Mitman, Jeffrey

From:	Ferrante, Fernando NRR
Sent:	Wednesday, February 03, 2010 3:20 PM
To:	James, Lois
Cc:	Mitman, Jeffrey
Subject:	Sensitivity Analysis
Attachments:	Memo for the Sensitivity Analysis.doc; sensitivity summary Rev.4.doc; Breach Parameter Matrix.xls

Lois,

Per our discussion, please find attached.

Thank you,

Fernando Ferrante, Ph.D.
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Division of Risk Assessment (DRA)
Operational Support and Maintenance Branch (APOB)
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B-83

Subject: NRR/DRA/APOB Preliminary Analysis of 1D dam breach modeling runs for the flooding evaluation of the Oconee Nuclear Station (ONS) due to an upstream dam failure

Dear XXXXXXXXX,

Please find attached a preliminary analysis developed by the Office of Nuclear Reactor Regulation, Division of Risk Assessment, PRA Operational Support Branch (NRR/DRA/APOB) in order to perform an initial evaluation of the 101 runs of a 1D dam breach modeling analysis developed by Duke Energy as part of their approach to sensitivity analysis of potential flooding effects at Oconee Nuclear Station (ONS) due to a piping failure of a large dam upstream of the site.

This preliminary analysis provides insights into the data provided without the benefit of a detailed explanation or key to the results presented. An Excel spreadsheet is attached to this document that presents the results in a more amenable form for review. The results of this effort are presented to you as a potential aid in the on-going discussions with the licensee regarding the sensitivity analysis.

Sincerely,
XXXXXXXXX

GENERAL COMMENTS

- The comments and results presented below were derived from an Excel spreadsheet (see attached) that contains 101 runs of a 1D dam breach modeling analysis developed by Duke Energy as part of their approach to sensitivity analysis of potential flooding effects at Oconee Nuclear Station (ONS) due to a piping failure of a large dam upstream of the site (i.e., Jocassee Dam).

- Explanations and justifications for some of the variation of input parameters are provided in attachments to the November 30, 2009, Duke Energy letter to the NRC, which are a response to a request from the NRC on April 30, 2009. Previous discussions of the parameters used for the sensitivity study took place on May 11, 2009 (as described in a November 10, 2009 summary) and August 27, 2009 (presentation slides available).

- The spreadsheet obtained from the licensee was particularly challenging to analyze in terms of insights or the quality of the sensitivity performed. The input and output data was reorganized in order to allow for a coherent analysis of any possible insights (also attached).

COMMENTS ON INPUT PARAMETERS

- There are a total of 22 input parameters presented in the sensitivity data: 5 Manning's roughness coefficients, 4 time to failure parameters, 3 modeling parameters, and 9 geometric parameters (see attachment A for full list). The output is represented by 4 flood elevations values at 3 selected locations (Keowee Dam, Oconee Intake Dike, and World of Energy Swale).

- Specific discrete values have been used for each parameter (mentioned in interactions between NRC and Duke Energy). For example, for a specific time to failure (Jocassee Dam Failure Time), there are 7 potential values listed (i.e., 1.0, 2.0, 2.6, 2.8, 3.0, 4.0, and 5.0 hours) as input. However, for most inputs, there are either 2 or 3 possible values presented. A subset of all possible combinations for the potential parameters indicated was used for a total of 101 runs resulting in flood elevations at the selected site locations mentioned above.

- Only the 1st run had a value of the Jocassee Reservoir Elevation different than 1110 feet (i.e., 1108 feet was used). It most likely appears that this value was used to calibrate the updated model with the results used for the FERC 1992 Inundation Study. Additional parameters not varied in the analysis are mentioned in the May 11, 2009, presentation by the licensee.

- The input parameter describing Keowee Breach Side Slopes is described with three possibilities: (1:1,1:1), (1.5:1,1.5:1), and (3.45:1, 2:03:1). However, side slopes of (1.5:1, 1.5:1) were not used in any of the 101 runs.

- As mentioned by the licensee, a specific subset of 3 combinations from the listed potential values was used in the inputs for the Manning's roughness coefficients (see attachment B for the full list): 0.02, 0.025, 0.035 and 0.07. The Manning's number coefficient for the Reservoir Tributaries upstream of the Keowee Dam was maintained constant at 0.035 for all runs (i.e., no sensitivity appears to have been done for this parameter).

- Three modeling parameters inputs were considered: inclusion/exclusion of saddle dike failures, inclusion/exclusion of bypass flow, and Jocassee Dam Failure Progression Type (i.e., linear or sine wave).

- The following pairs of runs exhibit repeated inputs resulting in the same outputs: 7 & 34, 12 & 36, and 63 & 76. It is unclear why these repetitions were included in the analysis since it does not appear that a probabilistic sampling of input parameters was done.

- There are two sets of runs (59 & 60, and 64 & 66 & 67) that have equivalent inputs and different outputs. Since there are no other parameters listed and the physical model used is assumed to be deterministic, reasons for the discrepancies may be due to (i) typo, (ii) error in the transcription of the results, (iii) additional input parameters affecting the output not shown, or (iv) problems with the deterministic model. The discrepancies in output between this subset are not significant for the most part (i.e., not more than a few decimal places) indicating possible numerical approximations in the output. However, in the case of runs 59 & 60, the difference in the Keowee Tailrace Elevation flood depth is > 3 feet.

- If the input repetitions in the listed runs mentioned above were to be resolved, there would be 95 individual runs with different inputs, instead of the 101 runs presented.

COMMENTS ON OUTPUT PARAMETERS

- Considering the 95 runs without repetitions, the cumulative distributions derived for each output parameter are shown in Attachment B, along with indications for the mean, 90th interval, and a normal distribution fit to the results. A comparison between the three groups of Manning's coefficients described above is also presented. To add perspective to the results, it should be considered that the height above mean sea level for (i) Jocassee Dam is 1125 feet, (ii) for Keowee Dam is 815 feet, and (iii) for the ONS Intake Dike is 815 feet. Additionally, the ONS yard elevation is at 796 feet above mean sea level.

- Not all runs resulted in flooding elevation values at the World of Energy Swale. The first 76 runs resulted in "n/a" entries at this site location, possibly because the analysis does not indicate a significant elevation at this location using this subset of input parameters.

- The variation of the output parameters versus the input parameters has been plotted using a box and whiskers representation. Description from MATLAB Manual: "*The box has lines at the lower quartile, median, and upper quartile values. The whiskers are lines extending from each end of the box to show the extent of the rest of the data. Notches graph a robust estimate of the uncertainty about the means for box-to-box comparison. Outliers are data with values beyond the ends of the whiskers",* (indicated as '+'). *"If there is no data outside the whisker, a dot is placed at the bottom whisker."*

- Results are shown for all the runs and major subsets of runs (i.e., by Manning's coefficient subsets) including all non-repeated inputs (except the 1108 feet Jocassee Reservoir Elevation calibrations run. For the runs where a different output is obtained with equal input parameters, the larger output values are used.

- It is very important to note that, without further clarification at this point, the variability in the input parameters only reflects the choice of values made by the licensee, since it is unclear whether

the variation is a reflection of known uncertainties in the values or recalibration of the sensitivity analysis based on initial results. Additionally, because multiple input parameters are modified between runs, care needs to be exercised in relating changes between a single input parameter and an output parameter.

- The maximum elevation values obtained from the 101 runs are: (i) 847.5 feet at Keowee Headwater (Run 54), (ii) 811 feet at Keowee Tailrace (Run 33), (iii) 830.4 feet at ONS Intake Dike Headwater (Run 80), and 817 feet at World of Energy Swale (Runs 81 and 82). See Attachment B for the corresponding input values. However, it is unclear from the observed data whether the true bounding maximum values could be established from this analysis based on the most conservative input parameter subset already limited by the licensee's chosen input values.

- For the 95 runs, it is challenging to establish clear trends between the output/input results (see Attachment B). However, some conclusions can be derived:

    - The group 1 subset of Manning's coefficients (all values equal to 0.035) causes smaller outputs of the ONS Intake Dike Headwater Elevation and higher results for the Keowee Tailrace Elevation. The smaller subset of results for the Keowee Headwater Elevation does not appear to show statistically significant differences between the three Manning's coefficient groups.

    - For the Keowee Headwater Elevation R_{Keowee}^{H}:

        - Increases in the R_{Keowee}^{H} output results are observed from increases in Keowee Overtopping Trigger parameter, Jocassee Piping Elevation, and the use of sine wave Jocassee Failure Progression versus a linear model.

        - Increases in R_{Keowee}^{H} are observed with lower values of the Jocassee Breach Bottom Width and when a value of 1 hour is used for Jocassee Dam Failure Time. A value of 600 feet for the Jocassee Breach Bottom Width also results in higher values for R_{Keowee}^{H}, although very few runs were made with larger widths of 625 feet and 650 feet to effectively establish its effects beyond 600 feet.

    - For the Keowee Tailrace Elevation R_{Keowee}^{T}:

        - An increase in R_{Keowee}^{T} values is observed with a decrease in Little River and Keowee Dam Failure Times, although this conclusion is cannot be conclusively extended to the other two time parameters.

        - Exclusion of Saddle Dam failures in the model results in a significant magnitude increase in elevation values

        - An increase in values of R_{Keowee}^{T} is observed with decreasing Keowee Overtopping Trigger Parameter, Jocassee Piping Elevation, and a Jocassee Side Slope configuration of 1:1 for both breach sides.

    - For the ONS Intake Dike Headwater Elevation $R_{Intake\ Dike}^{H}$:

        - An increase results from decreasing Jocassee Dam Failure Time. It is unclear that the remaining time parameters follow this trend, it seems in fact that larger elevations result from an increase in failure time for Little River, ONS Intake Dike, and Keowee.

        - Inclusion of Saddle Dam failures in the model results in a increase in elevation values
        - An increase in output values results in an increase in Jocassee Piping Elevation
    - For the World of Energy Swale Elevation R_{WE}^{S}:
        - An increase in the output results occurs from an increase in Little River and ONS Intake Canal Dike failure times, although it should be noted that a limited subset of values was produced for this output parameter

- For Group 1 Manning's coefficient input parameters, the most significant contributors to an increase in R_{Keowee}^{H} appear to be a decrease in the Jocassee Dam Failure Time and an increase in the Jocassee Piping Elevation (see Attachment C1 for output variation in other parameters).
- For Group 2 Manning's coefficient input parameters, the most significant contributors to an increase in R_{Keowee}^{H} appear to be a decrease in the Jocassee Dam Failure Time and an increase in the Keowee Overtopping Trigger Elevation (see Attachment C2 for output variation in other parameters).
- For Group 3 Manning's coefficient input parameters, the most significant contributor to an increase in R_{Keowee}^{T}, appears to the exclusion of Saddle Dam failures. For other parameters, few samples were used to assess the sensitivity to various input values (see Attachment C3 for output variation in other parameters).

RECOMMENDATIONS FROM LITERATURE

The following excerpts were obtained from reports and papers discussing dam breach parameter modeling and guidance related to sensitivity analysis associated with flooding analysis due to dam failures.

Federal Emergency Management Agency, "The National Dam Safety Program Research Needs Workshop: Hydrologic Issues for Dams", Workshop Report, November 14-15, 2001, in Davis, California.

- "The Commission's guidelines for breach parameters is given in Table 1 of Appendix A of Chapter 2. In general, the average breach width should be between 2 and 4 times the height of the dam for earth or rock fill dams…" "Failure times range from 0.1 to 1.0 hours for earth or rock fill dams, and from 0.1 to 0.3 hours for gravity dams."
- "Because of the uncertainty of breaches, the consultant should perform a sensitivity analysis of these parameters. For projects with large reservoirs, conservative breach parameters should be adopted since the rate of draw down of the reservoir during a breach is significantly slower than it is for projects with smaller reservoirs."
- "Common Modeling Problems

    1. Failure to model the entire reservoir. If dynamic routing of the reservoir stead of level pool routing is done, the consultant needs to make sure the cross-sections extend upstream of the reservoir to the point where backwater effects no longer exist. The shape of the cross-sections also needs to be examined to make sure all the storage between the cross-sections is accounted for. In some cases, the consultant extended the cross-sections only part way

into the reservoir, effectively negating the storage upstream that could be released through a breach.

2. No sensitivity studies. Although the selected breach width may be at the conservative end of the accepted range given in our criteria, a larger breach width may result in a substantially higher incremental rise downstream. If the incremental rise is highly sensitive to the breach width, then this needs to be considered when selecting the breach width.

3. Improper use of the Manning's n values. The NWS DAMBRK program requires the user to provide the composite Manning's n values at each elevation. Therefore, for out-of-bank flood elevations the consultant needs to compute the composite Manning's n value based on the weighted wetted perimeter. In many cases, the consultant will select too high of a Manning's value for the out-of-bank elevations. Although not a major factor, this can effect the results in some analysis.

4. Improper spillway rating curve. In some cases, the reservoir was allowed to draw down during the beginning of the routing because the consultant did not adjust the rating curve for when the gates are closed to maintain the normal pool level. In other cases, the consultant adjusted the rating curve to correct this, but the simulation then appeared as though the licensee closed all the gates instantaneously when the reservoir receded below the normal maximum pool after the breach developed."

Wahl, T., "Prediction of Embankment Dam Breach Parameters", Dam Safety Research Report DSO-98-004, US Department of Interior, Bureau of Reclamation, Dam Safety Office, July 1998

- "The importance of different parameters varies with reservoir size. In large reservoirs, the peak discharge occurs when the breach reaches its maximum depth and width. Changes in reservoir head are relatively slight during the breach formation period. In these cases, accurate prediction of breach geometry is most critical."

- "The ultimate breach width and the rate of breach width expansion can dramatically affect the peak flowrate and resulting inundation levels downstream from the dam."

- "Accurately predicting the breach side slope angles is generally of secondary importance to predicting the breach width and depth."

Wahl, T., "Uncertainty of Predictions of Embankment Dam Breach Parameters", Journal of Hydraulic Engineering, Vol. 130, No. 5, May 2004

- "The uncertainties of predictions of breach width, failure time, and peak outflow are large for all methods, and thus it may be worthwhile to incorporate uncertainty analysis results into future risk assessment studies when predicting breach parameters using these methods."

ATTACHMENT A

OVERALL OUTPUT PARAMETERS

R_{Keowee}^{H} = Keowee Headwater Elevation (feet)

R_{Keowee}^{T} = Keowee Tailrace Elevation (feet)

$R_{Intake\ Dike}^{H}$ = ONS Intake Dike Headwater Elevation (feet)

R_{WE}^{S} = World of Energy Swale Elevation (feet)

OVERALL INPUT PARAMETERS

Manning's number

$N_C^{D/S}$ = Keowee Downstream Channel = [0.02, 0.025, 0.035]

$N_{IT}^{D/S}$ = Keowee Downstream Immediate Tailrace = [0.035, 0.07]

$N_{RT}^{U/S}$ = Keowee Upstream Reservoir Tributaries = [0.035][1] [1]Constant in all runs

$N_C^{U/S}$ = Keowee Upstream Reservoir Channel = [0.02, 0.025, 0.035]

$N_{IT}^{U/S}$ = Keowee Upstream Immediate Tailrace = [0.035, 0.07]

Time to Failure

$T_{Little\ River}$ = Little River Dam Failure Time (hours) = [1.0, 1.6, 1.9, 2.4, 5.0]

$T_{Intake\ Dike}$ = ONS Intake Canal Dike (hours) = [0.8, 0.9, 1.0, 1.2, 2.0]

T_{Keowee} = Keowee Dam Failure Time (hours) = [2.0, 2.4, 2.8, 4.0]

$T_{Jocassee}$ = Jocassee Dam Failure Time (hours) = [1.0, 2.0, 2.6, 2.8, 3.0, 4.0, 5.0]

Modeling

W_{BF} = With Bypass Flow and Saddle Dam Failure = [Yes, No]

W_{SD} = With Bypass Flow and Saddle Dam Failure = [Yes, No]

FP = Jocassee Failure Progression = [linear, sine wave]

Geometric

S_{Keowee} = Keowee Side Slopes = [(1:1,1:1), (1.5:1,1.5:1)[2], (3.45:1, 2:03:1)] [2]Not used on any runs

B_{Keowee}^{W} = Keowee Breach Bottom Width (feet) = [500, 650]

H_{Keowee}^{B} = Keowee Breach Bottom Elevation (feet) = [670, 700]

OT_{Keowee} = Keowee Overtopping Trigger (feet) = [815.5, 817]

$S_{Jocassee}$ = Jocassee Side Slopes = [(0.9:1,0.9:1), (1:1,1:1), (1.5:1,1.5:1), (1.55:1,1:1), (1.55:1,0.7:1)]

$B_{Jocassee}^{W}$ = Jocassee Breach Bottom Width (feet) = [250, 425, 500, 600, 625, 650]

$H_{Jocassee}^{B}$ = Jocassee Breach Bottom Elevation (feet) = [750, 800, 825, 850]

$H_{Jocassee}^{P}$ = Jocassee Piping Elevation (feet) = [940, 1020]

$H_{Jocassee}^{R}$ = Jocassee Reservoir Elevation (feet) = [1108, 1110]

SUBSET RUNS

GROUP 1

Fixed	Manning's number	$N_C^{D/S} = 0.035$
	Geometric Parameters	$S_{Keowee} = (1{:}1,1{:}1)$, $H_{Jocasse}^{R} = 1110$ feet
Constant	Manning's number	$N_C^{D/S} = N_{IT}^{D/S} = N_{RT}^{U/S} = N_C^{U/S} = N_{IT}^{U/S} = 0.035$
	Time to failure	$T_{Little\ River} = T_{Intake\ Dike} = 1$ hour, $T_{Keowee} = 2$ hours
	Geometric Parameters	$B_{Keowee}^{W} = 500$ feet, $H_{Keowee}^{B} = 670$ feet
Varying	W_{BF} = [Yes, No],	
	W_{SD} = [Yes, No],	
	OT_{Keowee} = [815.5, 817],	
	FP = [linear, sine wave],	
	$T_{Jocassee}$ = [1.0, 2.0, 2.6, 2.8, 3.0, 4.0, 5.0]	
	$H_{Jocassee}^{P}$ = [940, 1020],	
	$S_{Jocassee}$ = [(0.9:1,0.9:1), (1:1,1:1), (1.5:1,1.5:1), (1.55:1,1:1), (1.55:1,0.7:1)],	
	$B_{Jocassee}^{W}$ = [250, 425, 500, 600, 625, 650],	
	$H_{Jocassee}^{B}$ = [750, 800, 825, 850]	

[Values in red were not used in this subset]

GROUP 2

Fixed	Manning's number	$N_C^{D/S}$ = 0.025
	Geometric Parameters	S_{Keowee} = (1:1,1:1), B_{Keowee}^{W} = 500 feet,
Constant	Manning's number	$N_{IT}^{D/S}$ = 0.07, $N_{RT}^{U/S}$ = 0.035, $N_C^{U/S}$ = 0.025,
		$N_{IT}^{U/S}$= 0.07
	Geometric Parameters	OT_{Keowee} = 817 feet,
		$H_{Jocassee}^{B}$ = 800 feet, $H_{Jocasse}^{R}$ = 1110 feet, FP = sine wave,
		$H_{Jocassee}^{P}$ = 1020 feet
	Modeling Parameters	W_{BF} = No,
Varying	$T_{Little\ River}$ = [1.0, 1.6, 1.9, 2.4, 5.0]	
	$T_{Intake\ Dike}$ = [0.8, 0.9, 1.0, 1.2, 2.0]	
	W_{SD} = [Yes, No],	
	T_{Keowee} = [2.0, 2.4, 2.8, 4.0]	
	H_{Keowee}^{B} = [670, 700]	
	$T_{Jocassee}$ = [1.0, 2.0, 2.6, 2.8, 3.0, 4.0, 5.0]	
	$S_{Jocassee}$ = [(0.9:1,0.9:1), (1:1,1:1), (1.5:1,1.5:1), (1.55:1,1:1), (1.55:1,0.7:1)],	
	$B_{Jocassee}^{W}$ = [250, 425, 500, 600, 625, 650]	

[Values in red were not used in this subset]

GROUP 3

Fixed	Manning's number	$N_C^{D/S}$ = 0.020
Constant	Manning's number	$N_{IT}^{D/S}$ = 0.07, $N_{RT}^{U/S}$ = 0.035, $N_C^{U/S}$ = 0.020, $N_{IT}^{U/S}$= 0.07
	Geometric Parameters	$T_{Little\ River}$ = $T_{Intake\ Dike}$ = 1 hour, T_{Keowee} = 2 hours, S_{Keowee} = (1:1,1:1), B_{Keowee}^{W} = 500 feet, $H_{Jocassee}^{B}$ = 800 feet, $H_{Jocasse}^{R}$ = 1110 feet, H_{Keowee}^{B} = 670 feet

Varying

W_{BF} = [Yes, No],

W_{SD} = [Yes, No],

OT_{Keowee} = [815.5, 817],

FP = [linear, sine wave],

$T_{Jocassee}$ = [1.0, 2.0, 2.6, 2.8, 3.0, 4.0, 5.0]

H_{Keowee}^{B} = [670, 700]

$H_{Jocassee}^{P}$ = [940, 1020],

$S_{Jocassee}$ = [(0.9:1,0.9:1), (1:1,1:1), (1.5:1,1.5:1), (1.55:1,1:1), (1.55:1,0.7:1)],

$B_{Jocassee}^{W}$ = [250, 425, 500, 600, 625, 650],

[Values in red were not used in this subset]

ATTACHMENT B

INPUT PARAMETERS RESULTING IN MAXIMUM KEOWEE HEADWATER ELEVATION (849.7 FT)

	Keowee D/S Manning's number		Keowee U/S Manning's number			Little River Dam Parameters	ONS Intake Canal Dike	W Bypass Flow	W Saddle Dam	Keowee Parameters					Jocassee Parameters						
Run (#)	$N_C^{D/S}$	$N_{IT}^{D/S}$	$N_{RT}^{U/S}$	$N_C^{U/S}$	$N_{IT}^{U/S}$	$T_{Little\ River}$	$T_{Intake\ Dike}$	W_{BF}	W_{SD}	T_{Keowee}	OT_{Keowee}	S_{Keowee}	B_{Keowee}^{W}	H_{Keowee}^{B}	FP	T_{Keowee}	$H_{Jocassee}^{P}$	$S_{Jocassee}$	$B_{Jocassee}^{W}$	$H_{Jocassee\ B}$	$H_{Jocassee}^{R}$
54	0.035	0.035	0.035	0.035	0.035	1	1	0	0	2	817	1	500	670	1	1	1020	3	600	800	1110

INPUT PARAMETERS RESULTING IN MAXIMUM KEOWEE TAILRACE ELEVATION (811 FT)

	Keowee D/S Manning's number		Keowee U/S Manning's number			Little River Dam Parameters	ONS Intake Canal Dike	W Bypass Flow	W Saddle Dam	Keowee Parameters					Jocassee Parameters						
Run (#)	$N_C^{D/S}$	$N_{IT}^{D/S}$	$N_{RT}^{U/S}$	$N_C^{U/S}$	$N_{IT}^{U/S}$	$T_{Little\ River}$	$T_{Intake\ Dike}$	W_{BF}	W_{SD}	T_{Keowee}	OT_{Keowee}	S_{Keowee}	B_{Keowee}^{W}	H_{Keowee}^{B}	FP	T_{Keowee}	$H_{Jocassee}^{P}$	$S_{Jocassee}$	$B_{Jocassee}^{W}$	$H_{Jocassee\ B}$	$H_{Jocassee}^{R}$
33	0.035	0.035	0.035	0.035	0.035	1	1	0	0	2	815.5	1	500	670	2	3	1020	3	500	800	1110

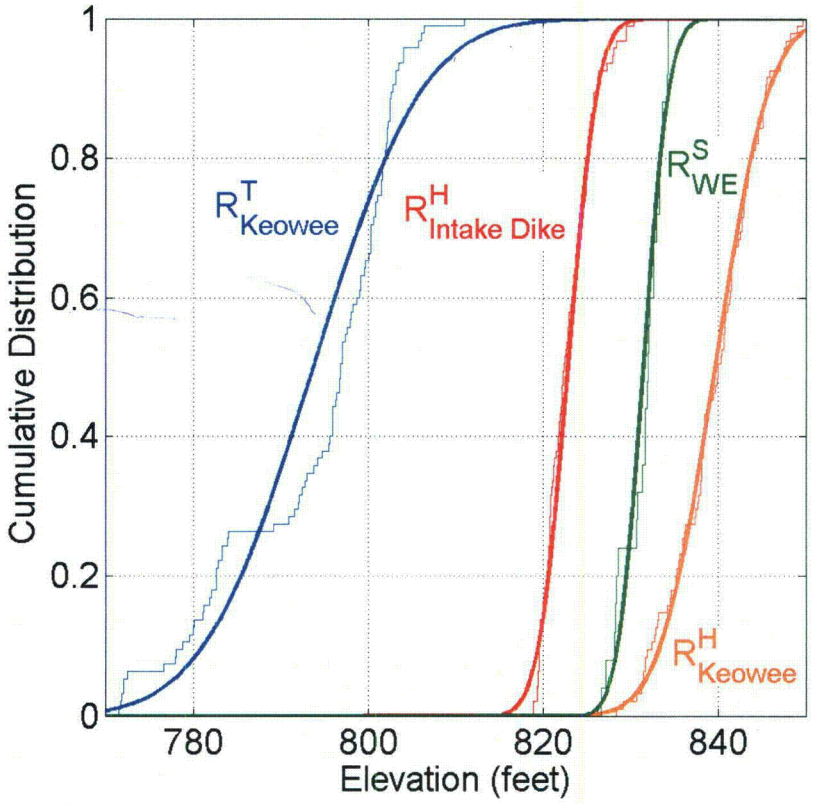
INPUT PARAMETERS RESULTING IN MAXIMUM ONS INTAKE DIKE HEADWATER ELEVATION (830.4 FT)

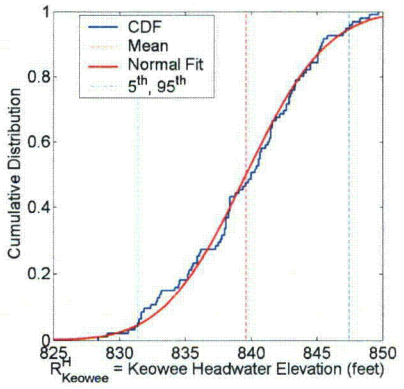
	Keowee D/S Manning's number		Keowee U/S Manning's number			Little River Dam Parameters	ONS Intake Canal Dike	W Bypass Flow	W Saddle Dam	Keowee Parameters					Jocassee Parameters						
Run (#)	$N_C^{D/S}$	$N_{IT}^{D/S}$	$N_{RT}^{U/S}$	$N_C^{U/S}$	$N_{IT}^{U/S}$	$T_{Little\ River}$	$T_{Intake\ Dike}$	W_{BF}	W_{SD}	T_{Keowee}	OT_{Keowee}	S_{Keowee}	B_{Keowee}^{W}	H_{Keowee}^{B}	FP	T_{Keowee}	$H_{Jocassee}^{P}$	$S_{Jocassee}$	$B_{Jocassee}^{W}$	$H_{Jocassee\ B}$	$H_{Jocassee}^{R}$
80	0.025	0.07	0.035	0.025	0.07	5	2	0	1	4	817	1	500	670	2	1	1020	2	500	800	1110

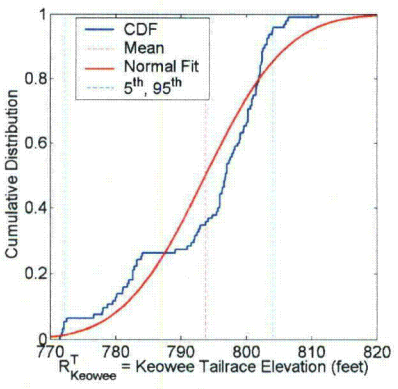
INPUT PARAMETERS RESULTING IN MAXIMUM WORLD OF ENERGY SWALE ELEVATION (817 FT)

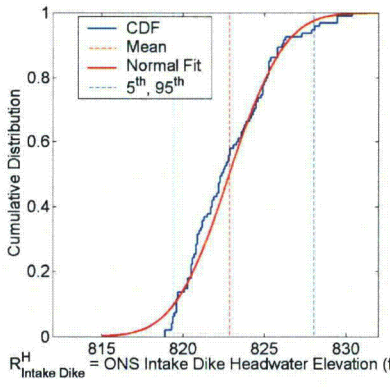
	Keowee D/S Manning's number		Keowee U/S Manning's number			Little River Dam Parameters	ONS Intake Canal Dike	W Bypass Flow	W Saddle Dam	Keowee Parameters					Jocassee Parameters						
Run (#)	$N_C^{D/S}$	$N_{IT}^{D/S}$	$N_{RT}^{U/S}$	$N_C^{U/S}$	$N_{IT}^{U/S}$	$T_{Little\ River}$	$T_{Intake\ Dike}$	W_{BF}	W_{SD}	T_{Keowee}	OT_{Keowee}	S_{Keowee}	B_{Keowee}^{W}	H_{Keowee}^{B}	FP	T_{Keowee}	$H_{Jocassee}^{P}$	$S_{Jocassee}$	$B_{Jocassee}^{W}$	$H_{Jocassee\ B}$	$H_{Jocassee}^{R}$
81	0.025	0.07	0.035	0.025	0.07	5	2	0	1	4	817	1	500	670	2	2	1020	2	500	800	1110
82	0.025	0.07	0.035	0.025	0.07	5	2	0	1	4	817	1	500	670	2	2	1020	4	500	800	1110

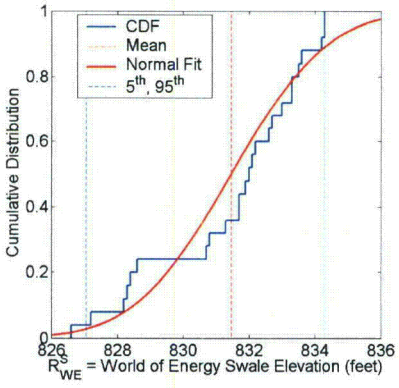
OVERALL RESULTS



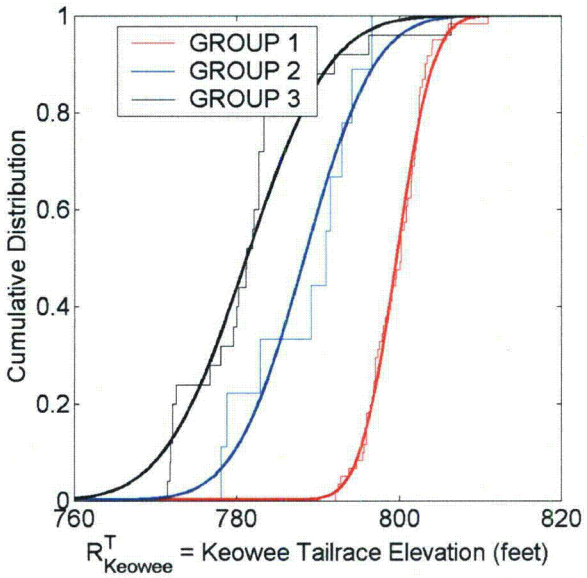


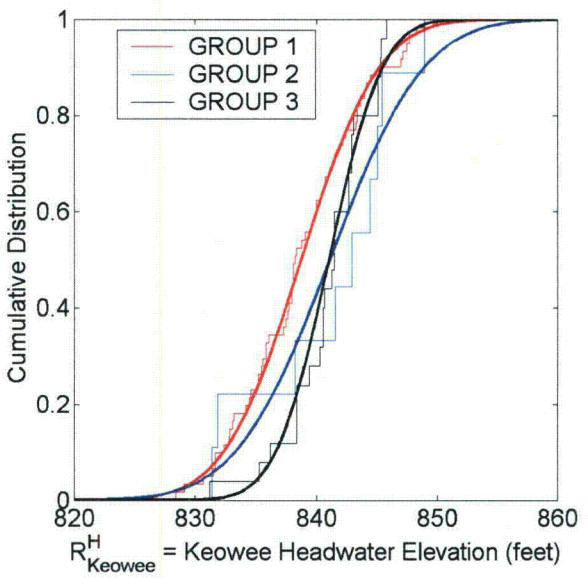


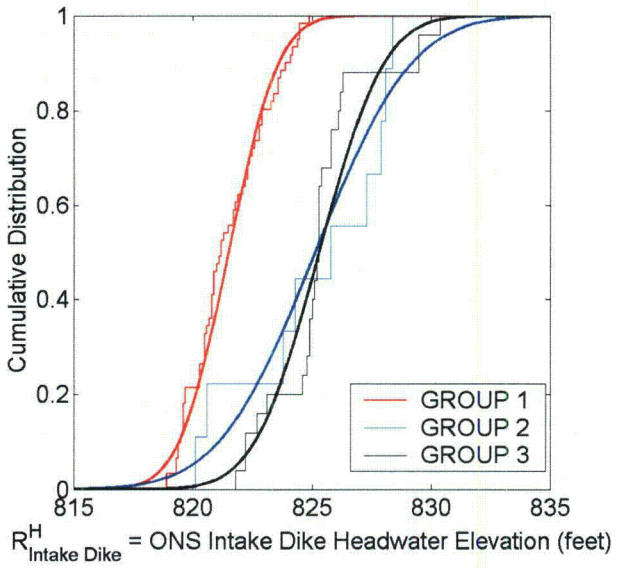




COMPARISON BETWEEN OUTPUT RESULTS FOR GROUPS 1, 2, AND 3

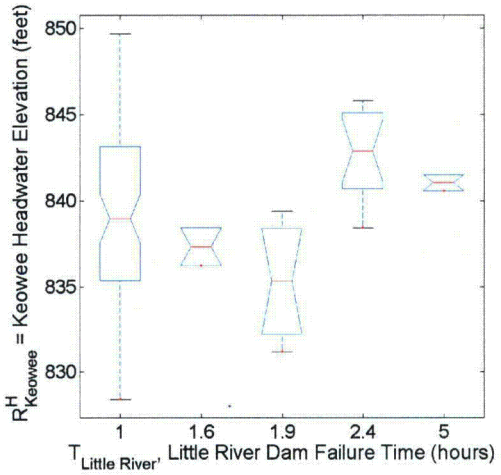


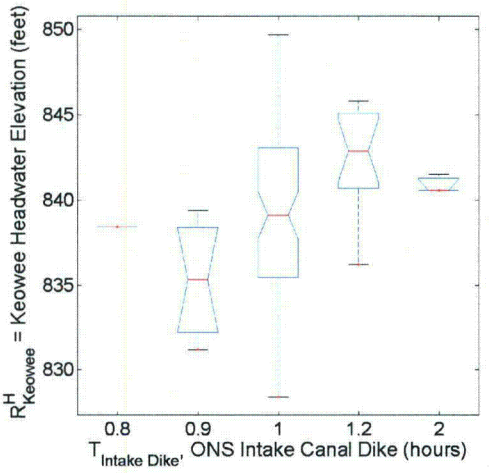


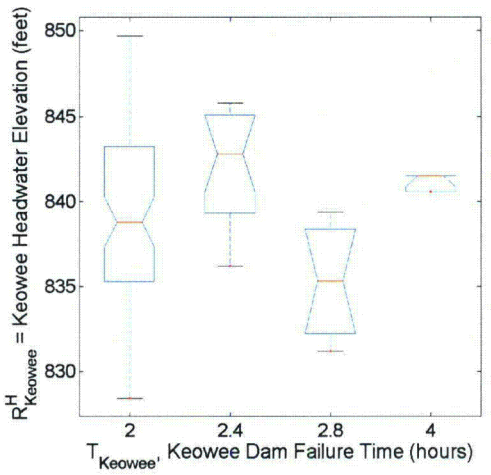


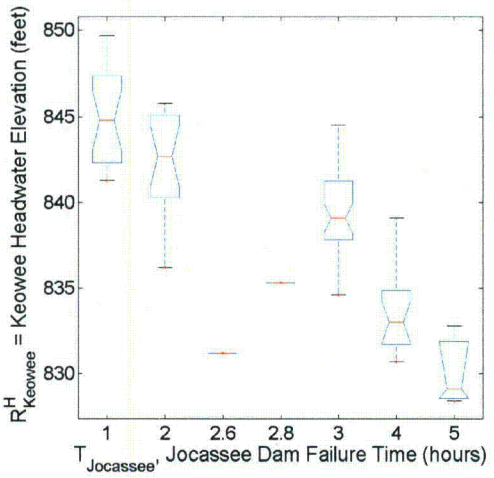
OVERALL VARIATION IN KEOWEE HEADWATER ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

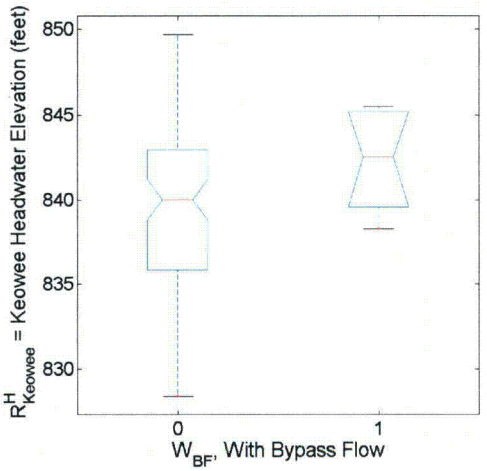


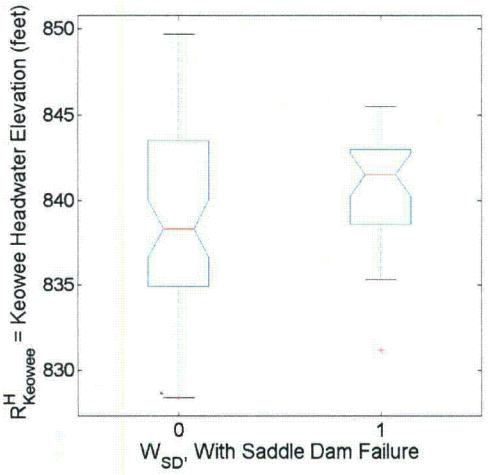


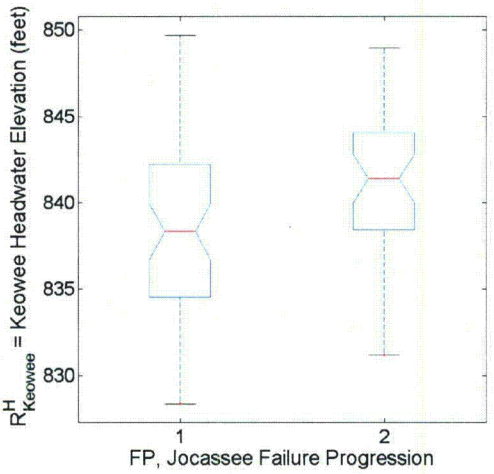




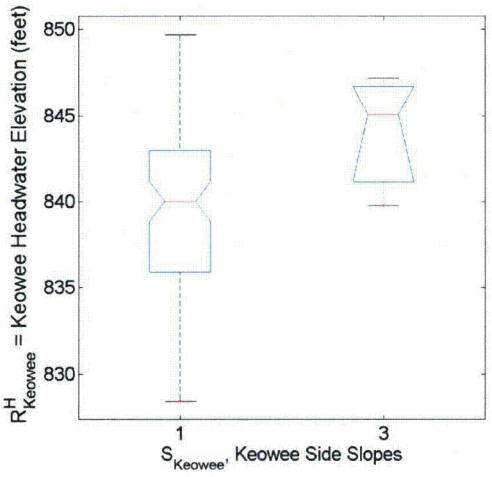
Modeling Parameters

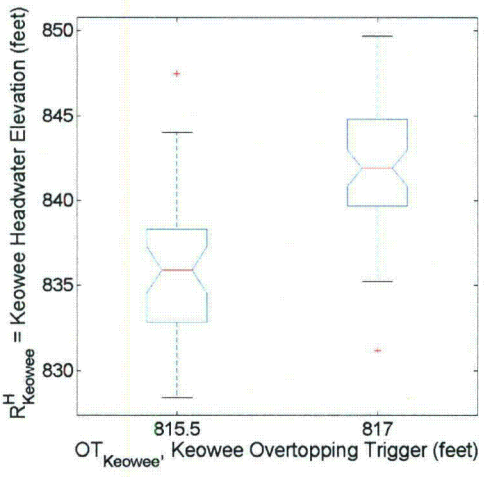


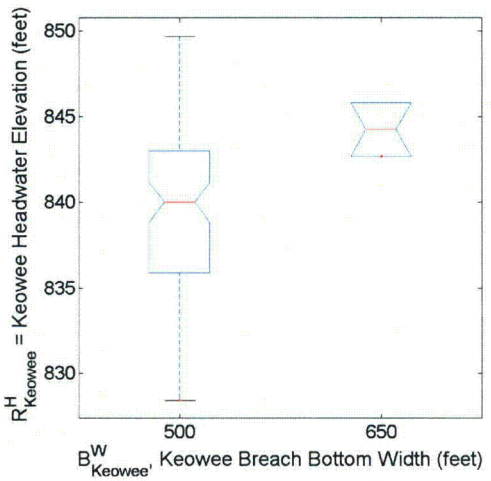


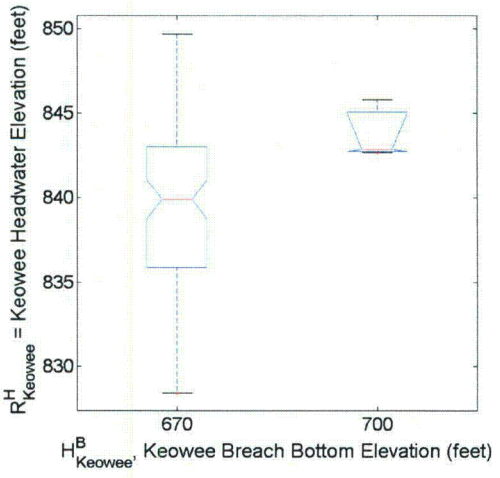


Geometric Parameters (Keowee)

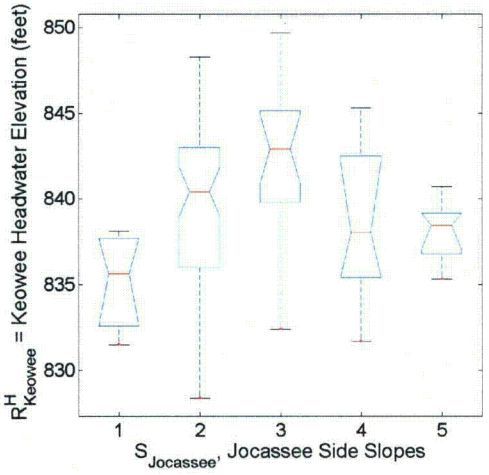


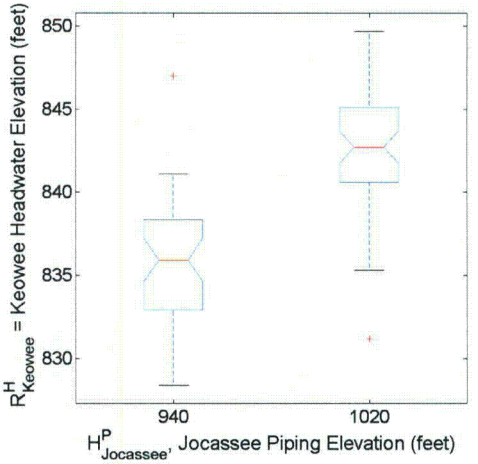


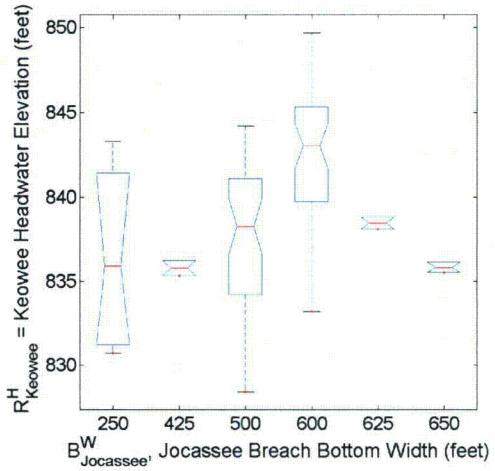


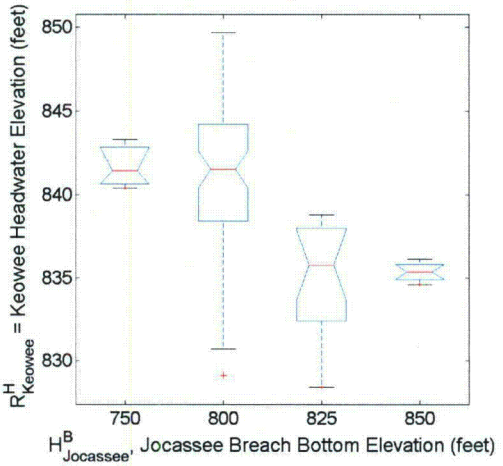


Geometric Parameters (Jocassee)



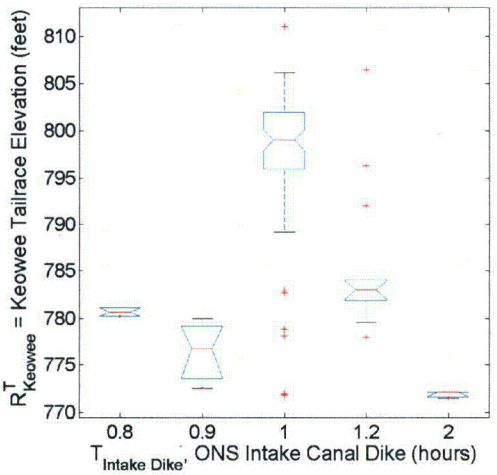


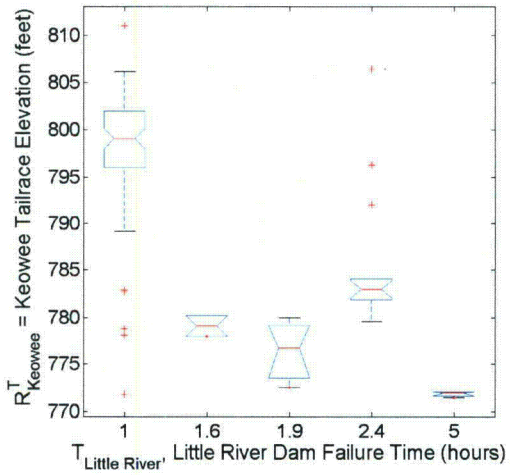


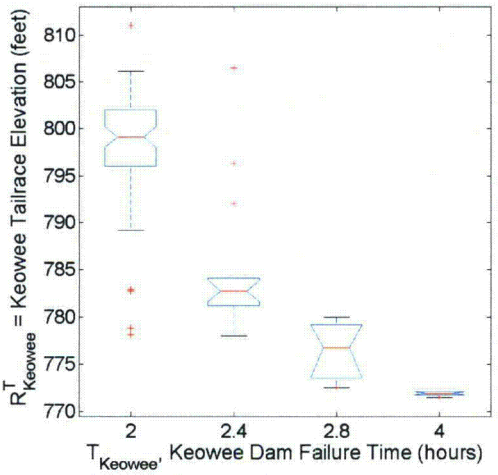


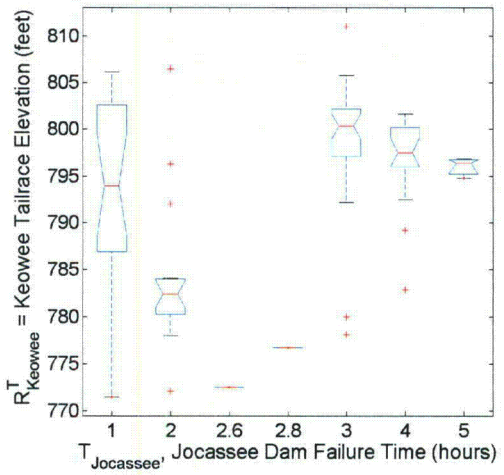
OVERALL VARIATION IN KEOWEE TAILRACE ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

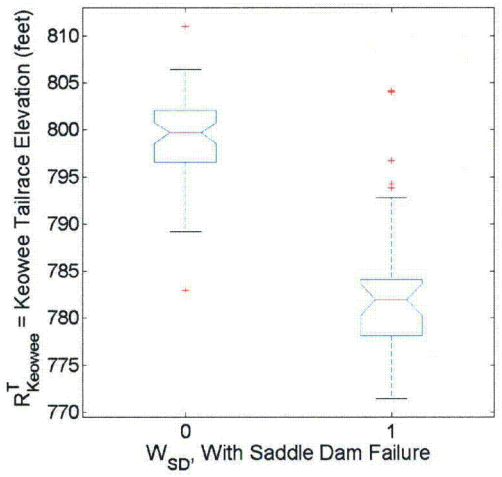


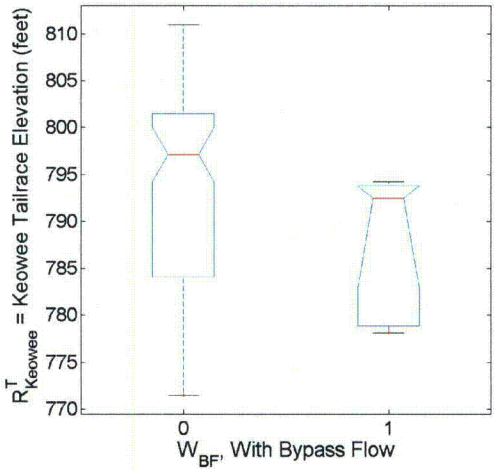


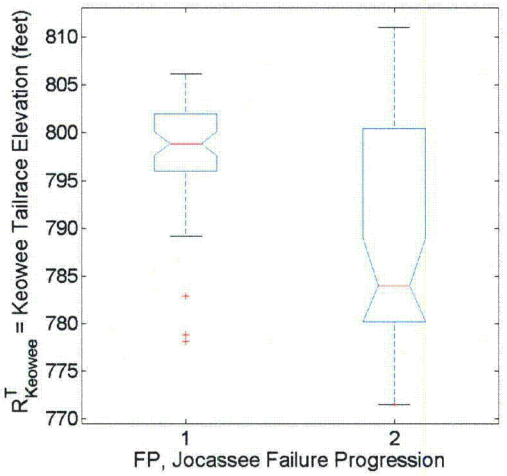




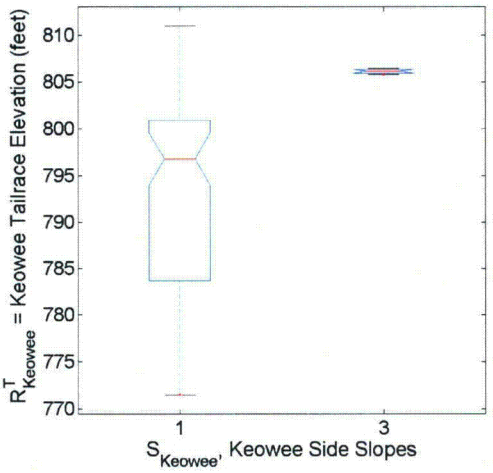
Modeling Parameters

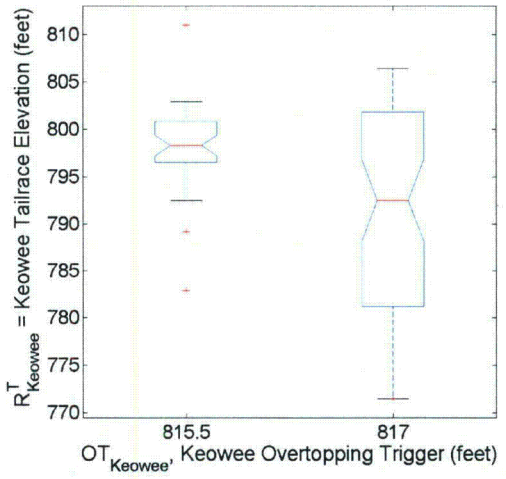


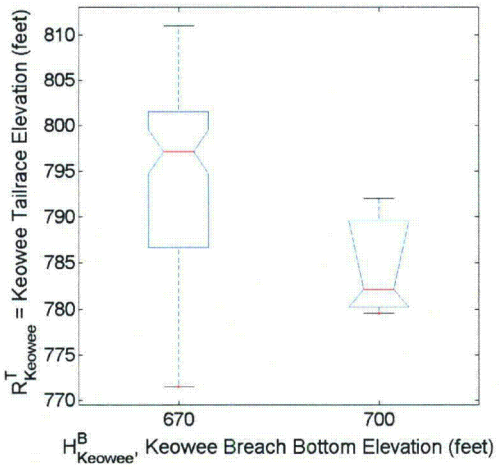


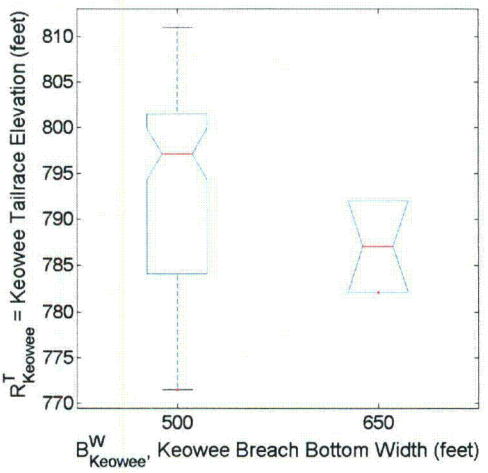


Geometric Parameters (Keowee)

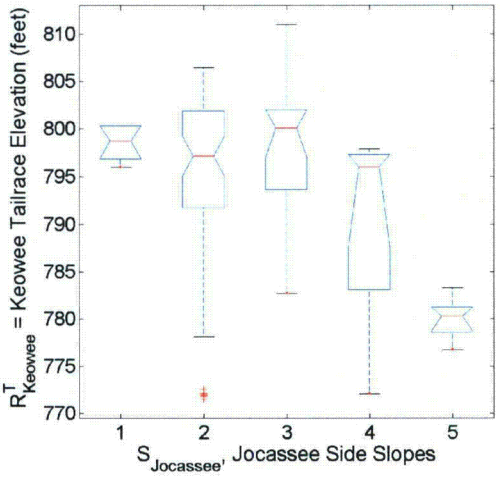


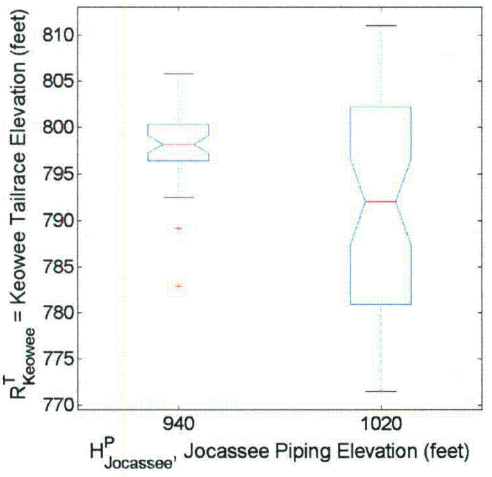


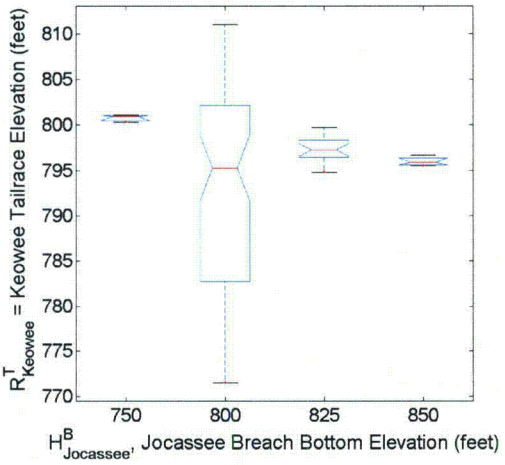


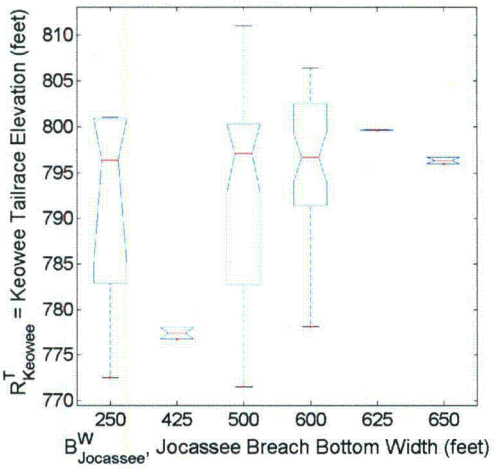


Geometric Parameters (Jocassee)



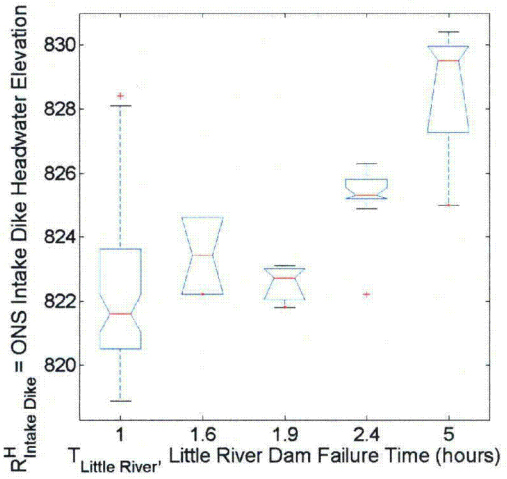


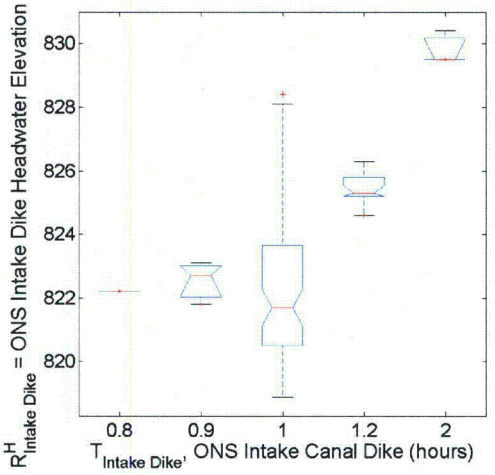


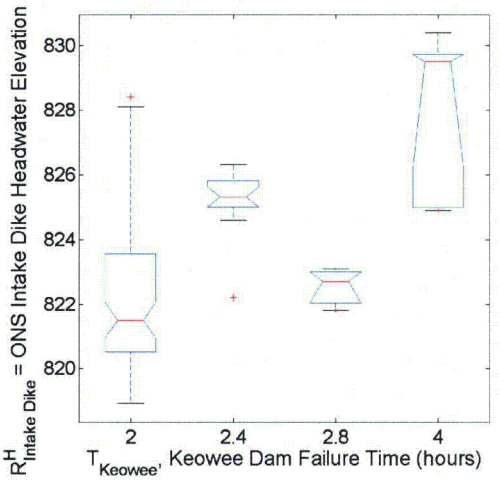


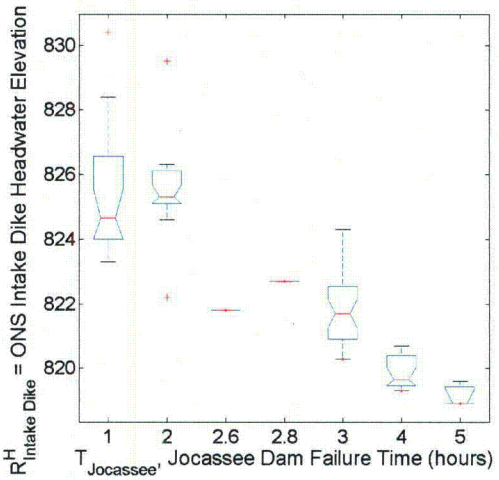
OVERALL VARIATION IN ONS INTAKE DIKE HEADWATER DUE TO INDIVIDUAL PARAMETERS

Time to Failure

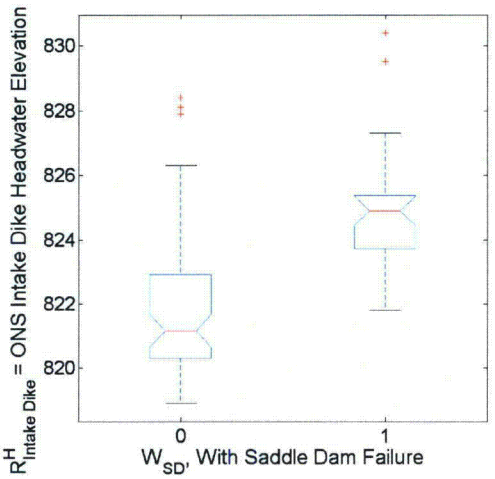


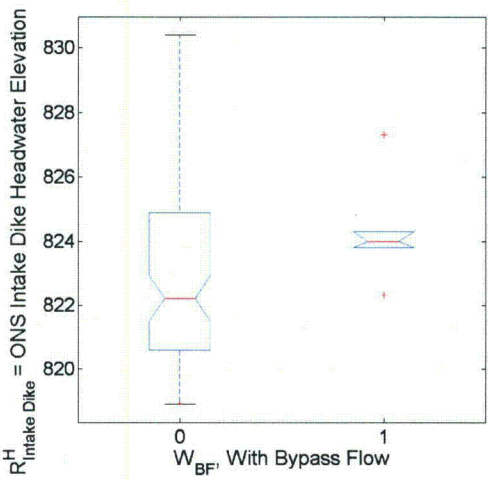


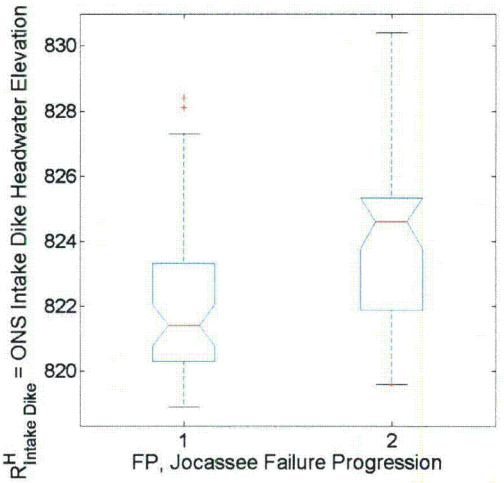




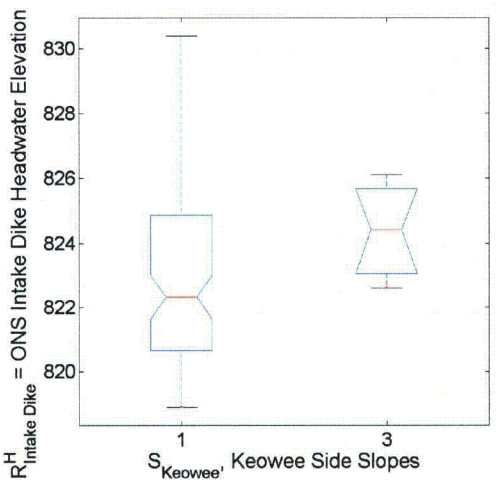
Modeling Parameters

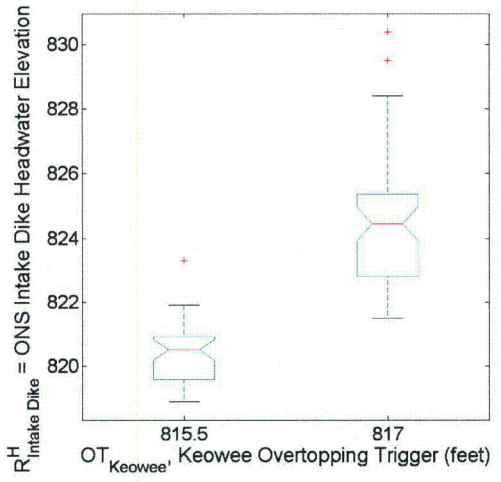


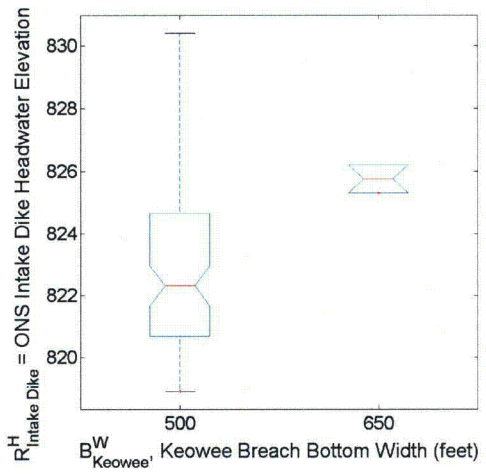


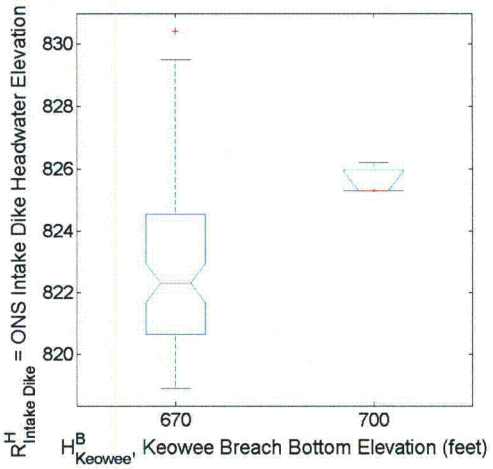


Geometric Parameters (Keowee)

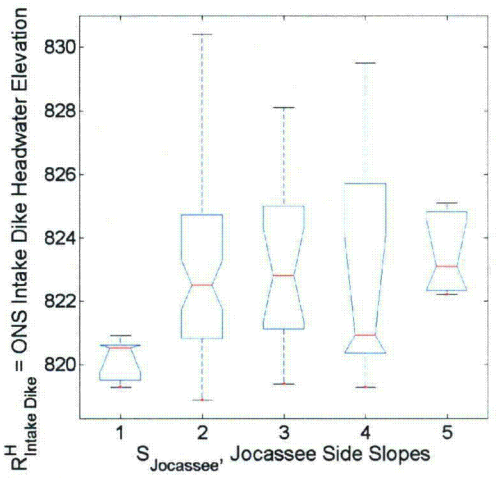


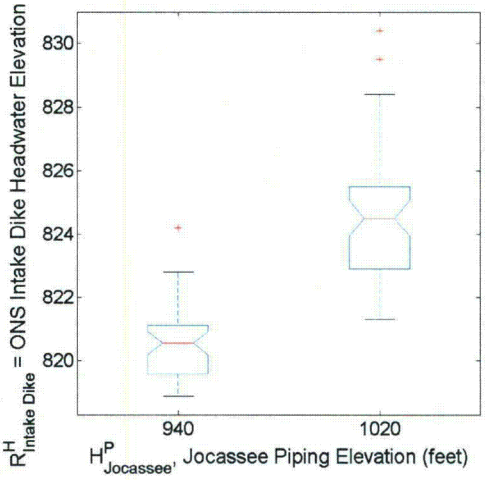


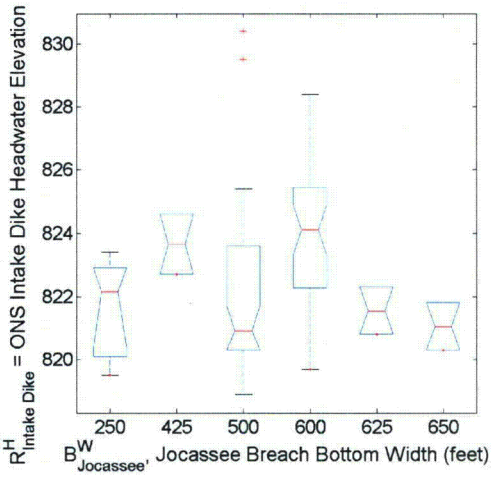


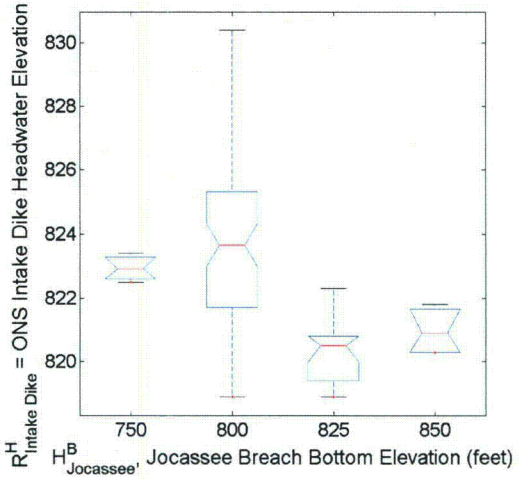


Geometric Parameters (Jocassee)



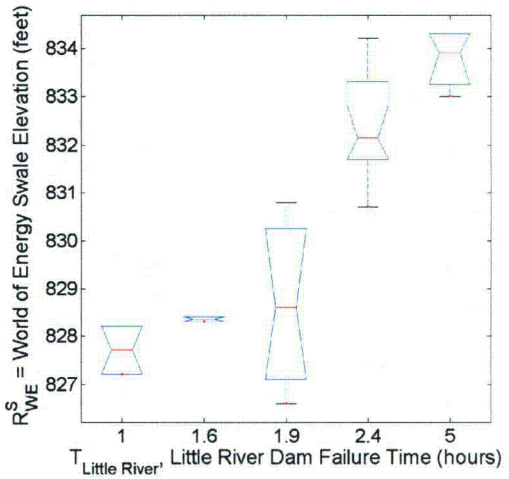


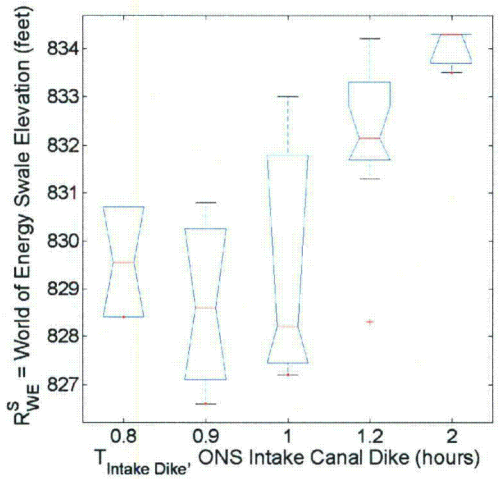


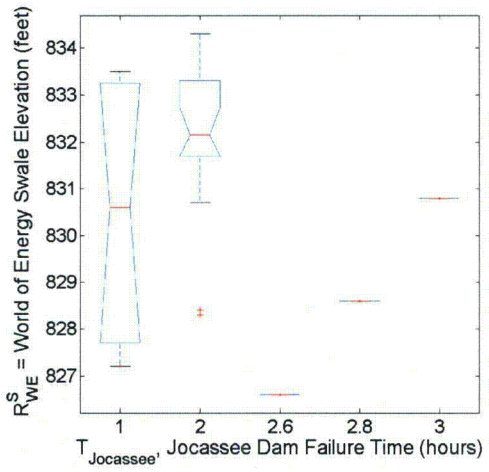


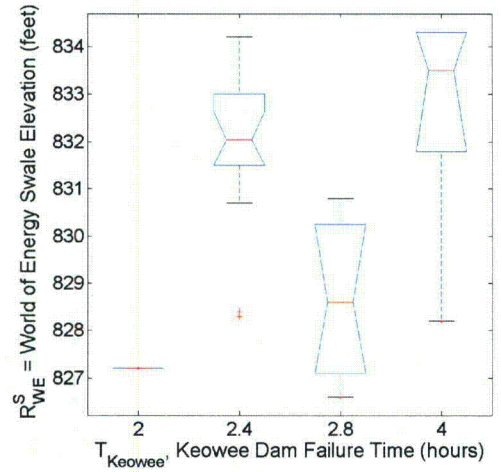
OVERALL VARIATION IN WORLD OF ENERGY SWALE ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

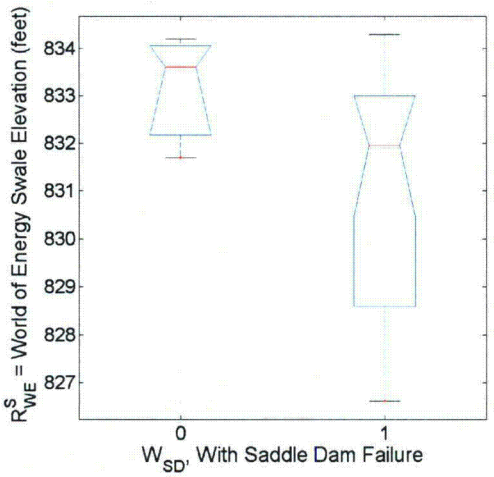




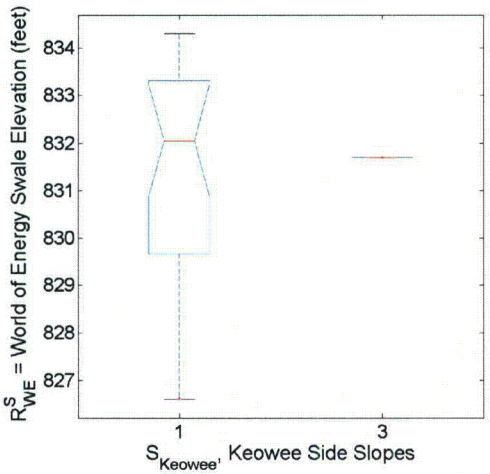


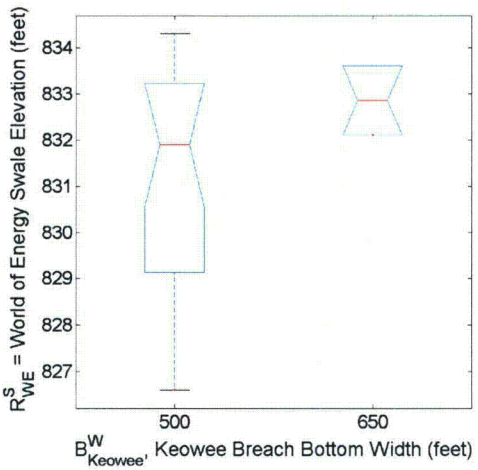


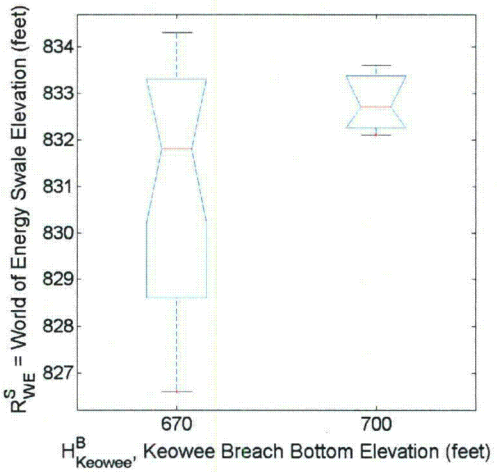
Modeling Parameters



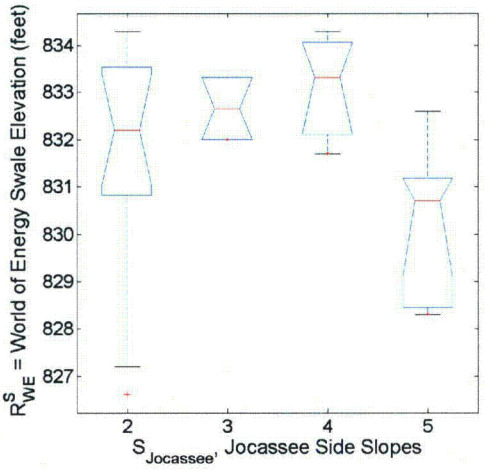
Geometric Parameters (Keowee)

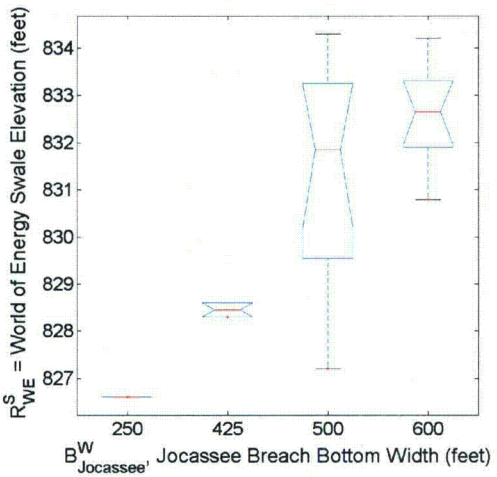






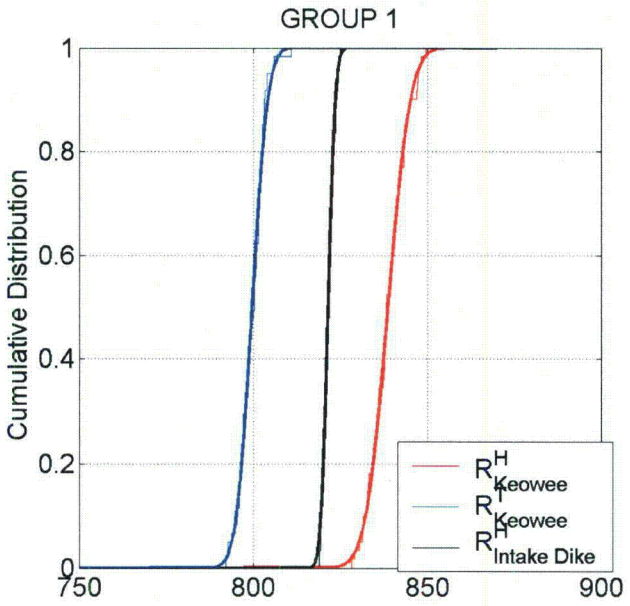
Geometric Parameters (Jocassee)

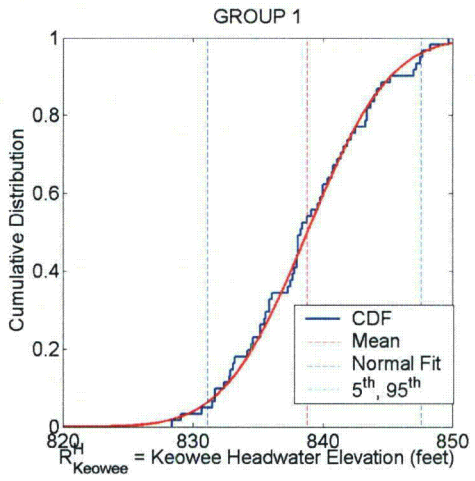


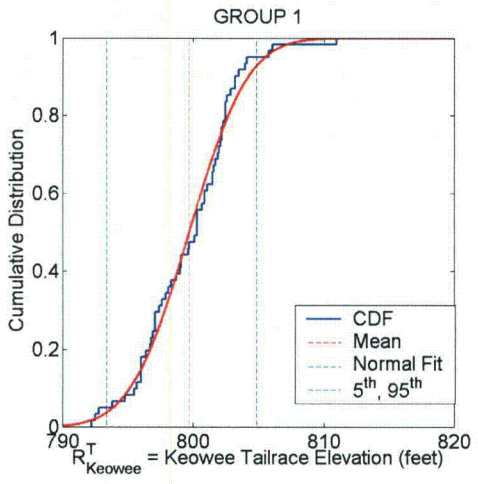


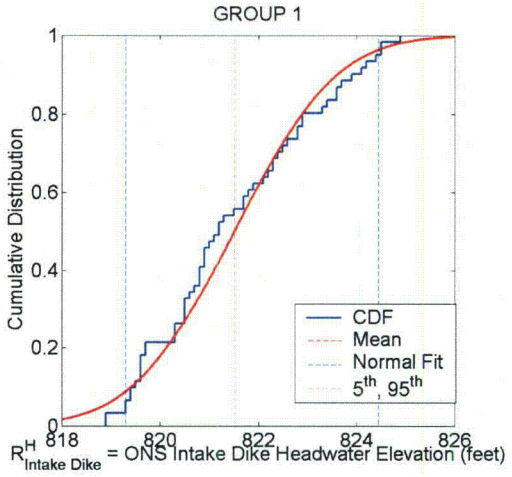
ATTACHMENT C1

GROUP 1 RESULTS



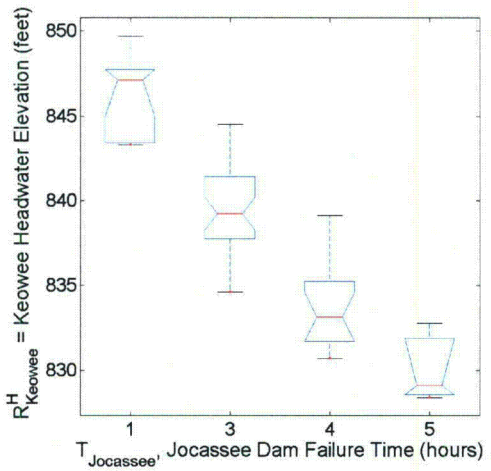




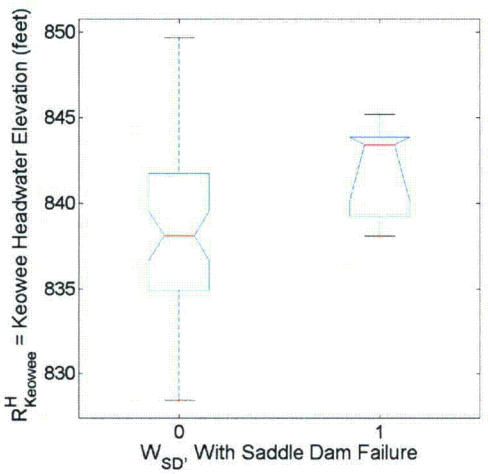


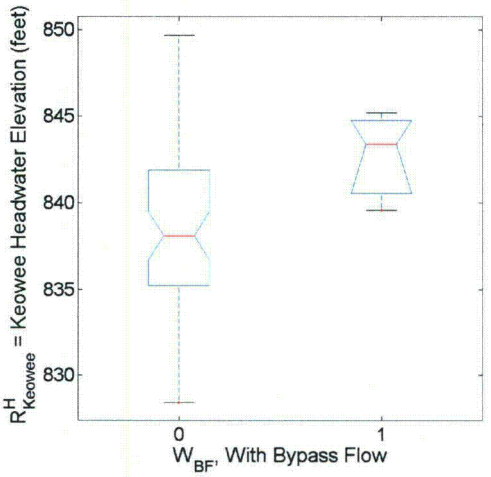
GROUP 1 VARIATION IN KEOWEE HEADWATER ELEVATION DUE TO INDIVIDUAL PARAMETERS

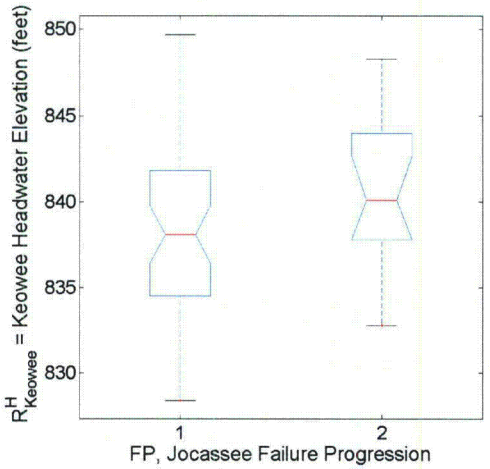
Time to Failure



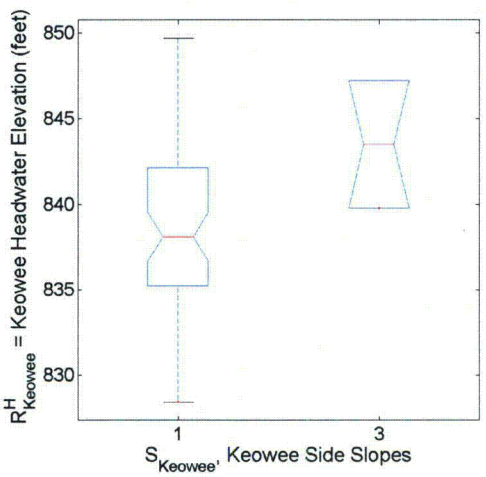
Modeling Parameters

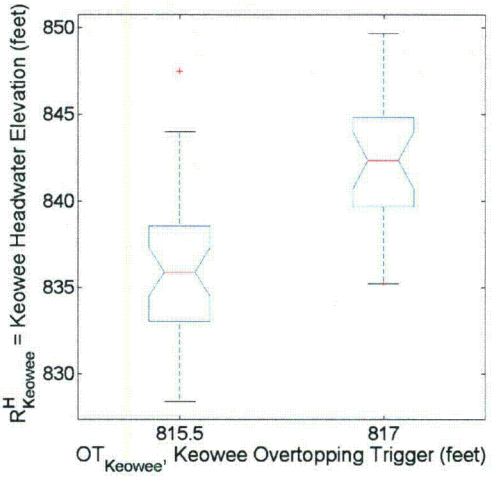




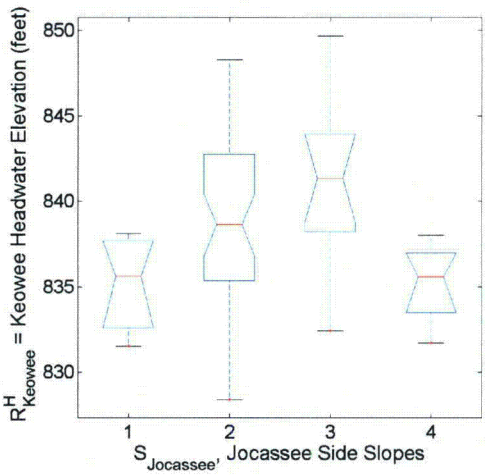


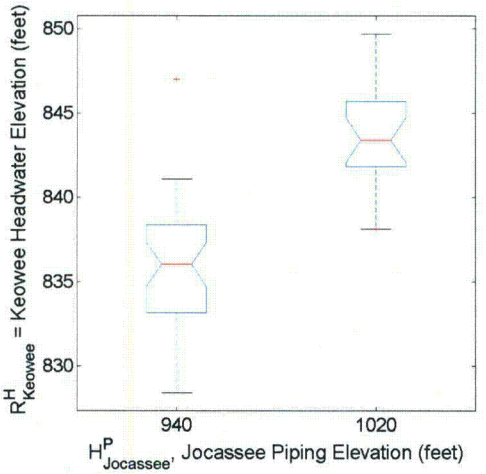
Geometric Parameters (Keowee)

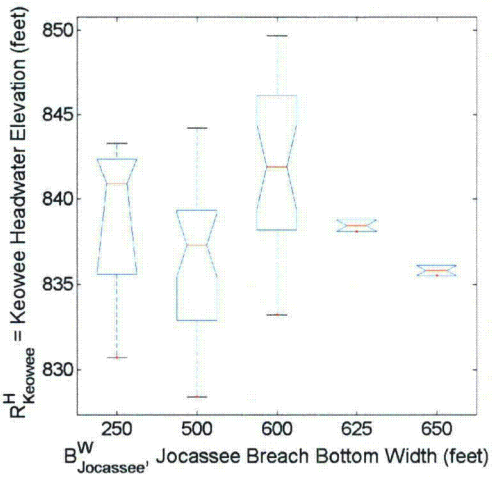


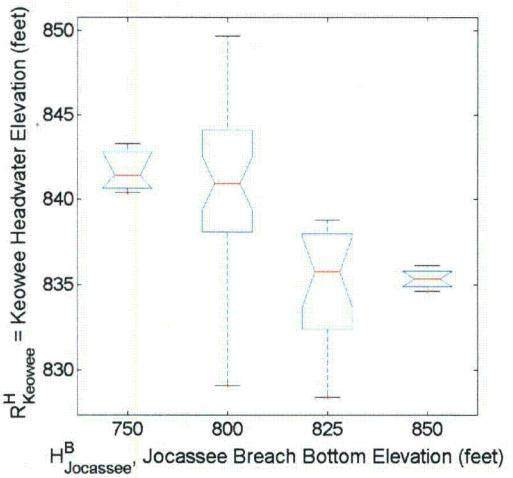


Geometric Parameters (Jocassee)



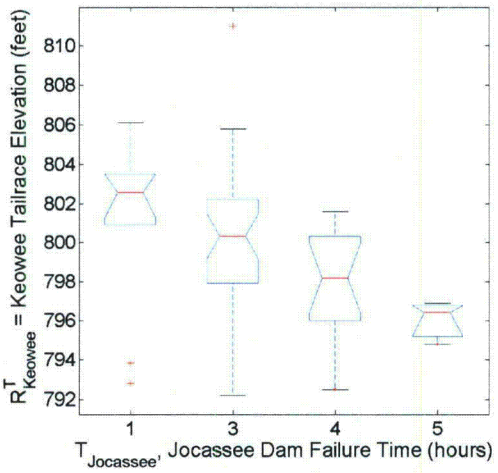




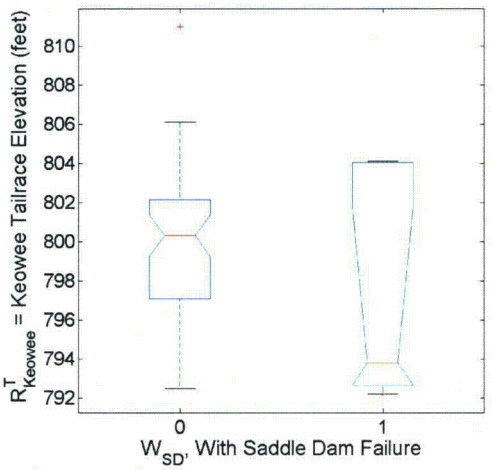


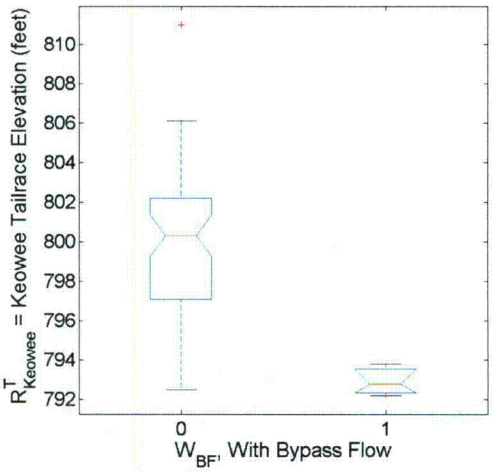
GROUP 1 VARIATION IN KEOWEE TAILRACE ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

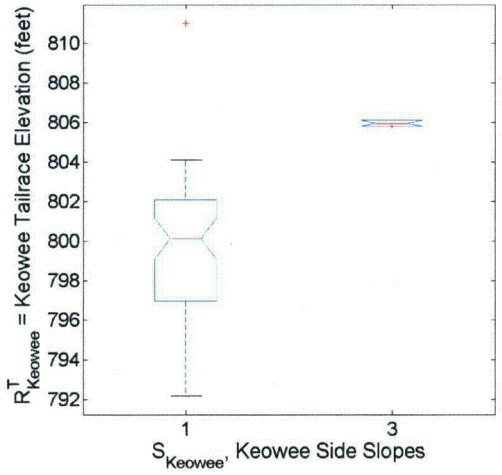


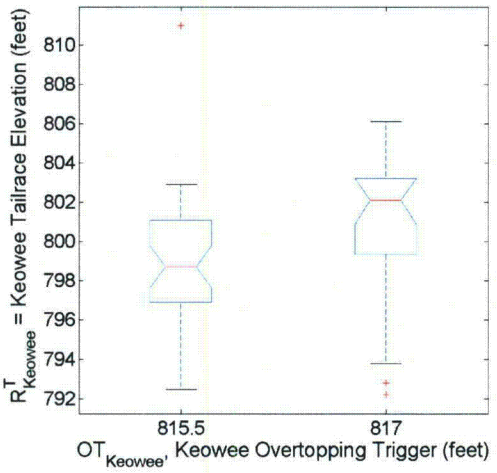
Modeling Parameters

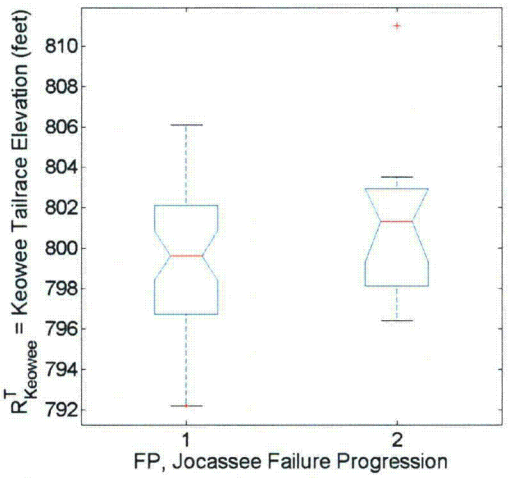




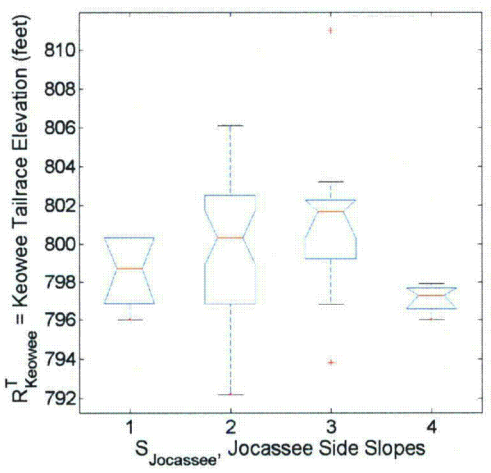
Geometric Parameters (Keowee)

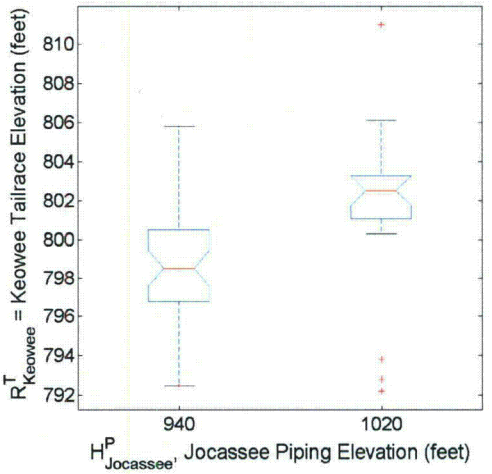


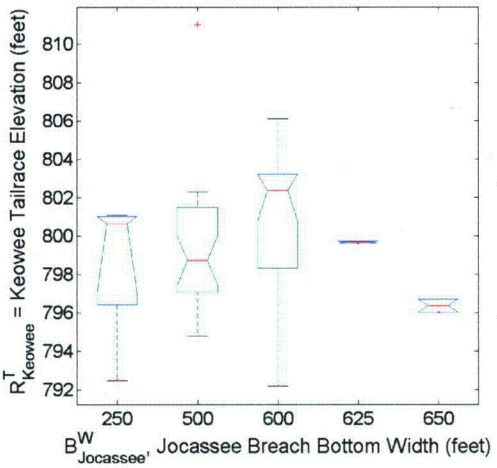


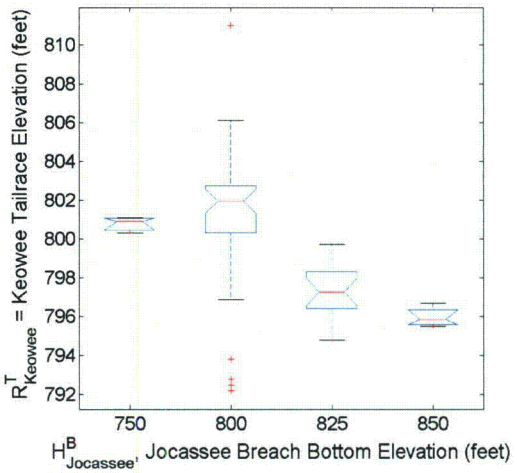


Geometric Parameters (Jocassee)



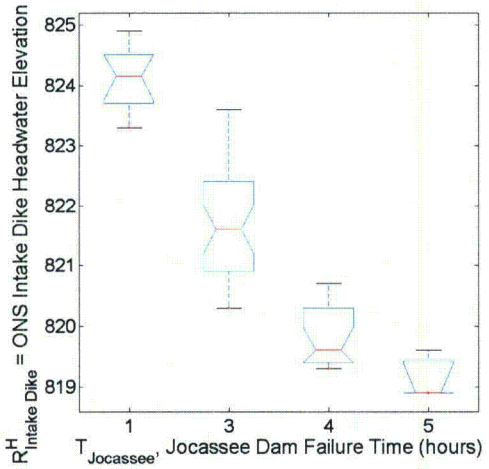




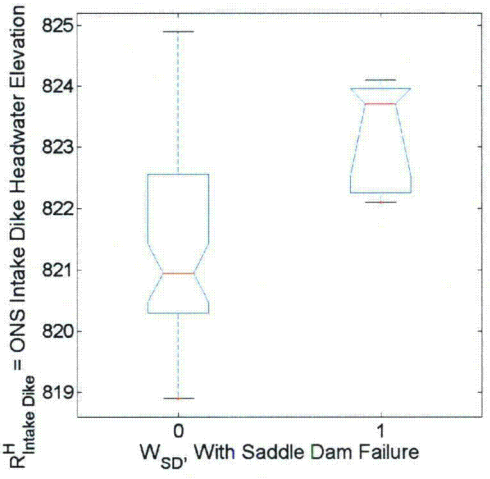


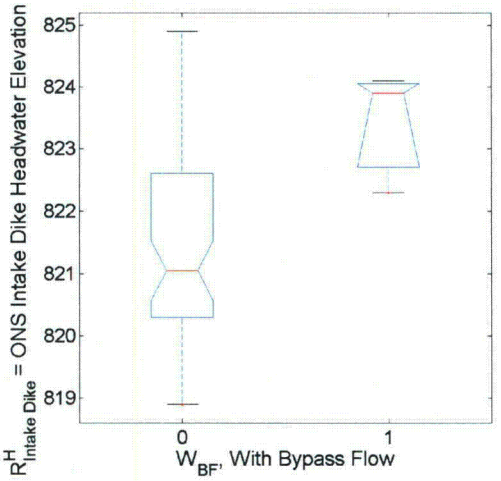
GROUP 1 VARIATION IN ONS INTAKE DIKE HEADWATER DUE TO INDIVIDUAL PARAMETERS

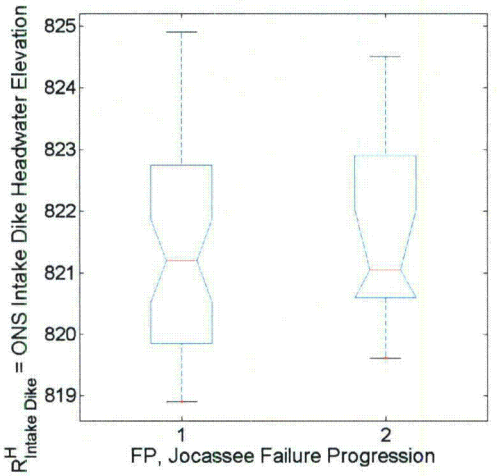
Time to Failure



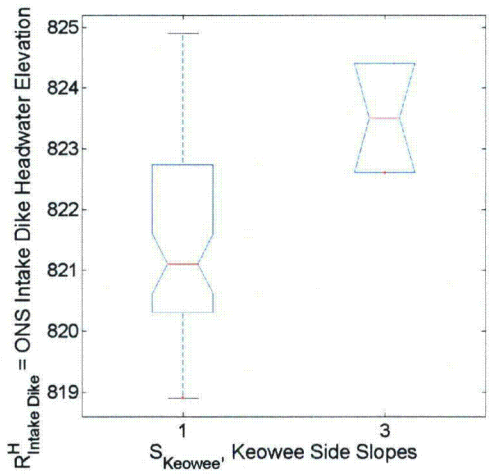
Modeling Parameters

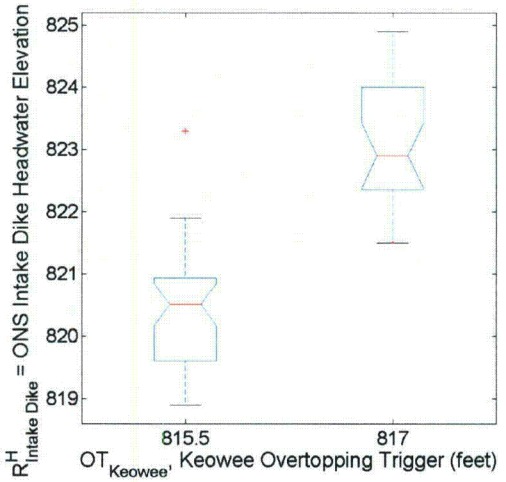




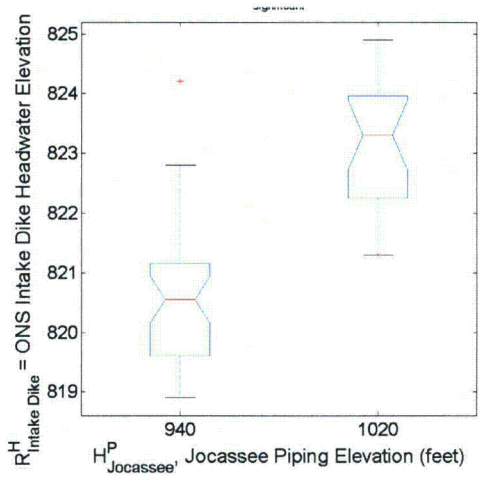


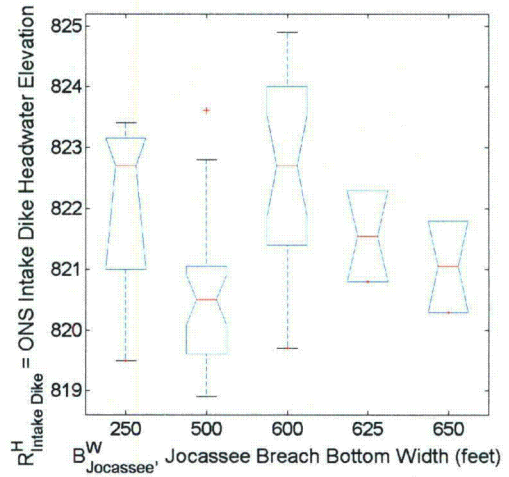
Geometric Parameters (Keowee)

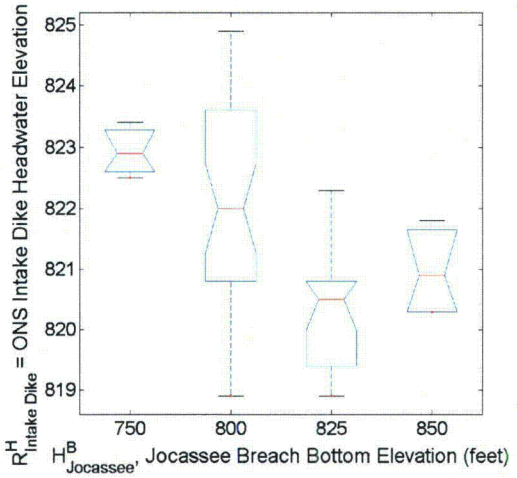


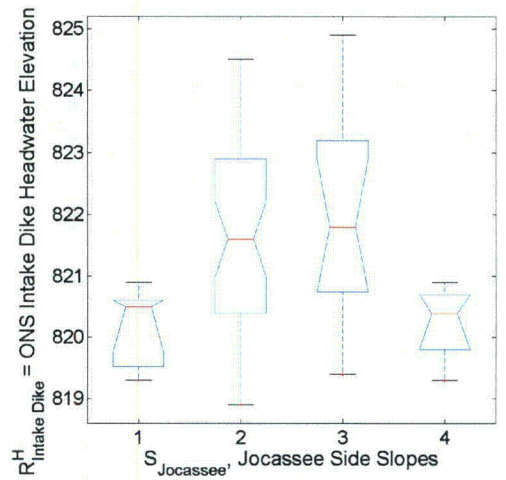


Geometric Parameters (Jocassee)



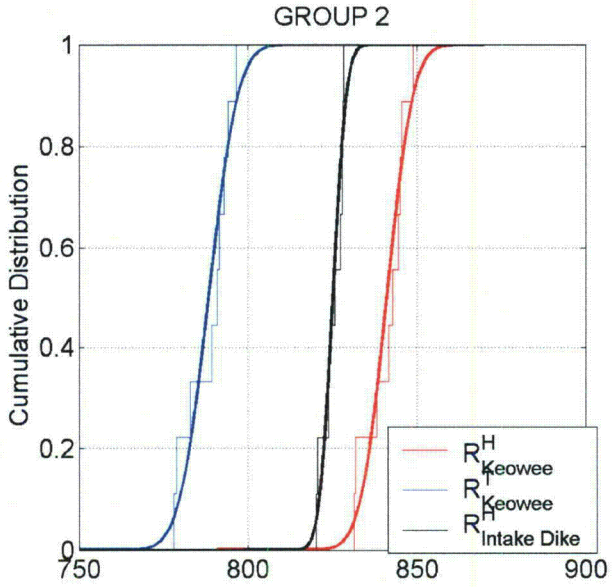


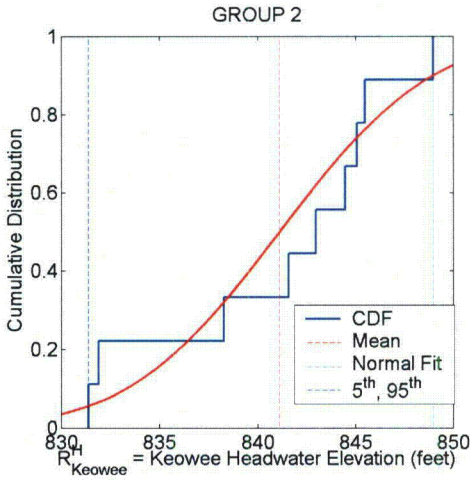


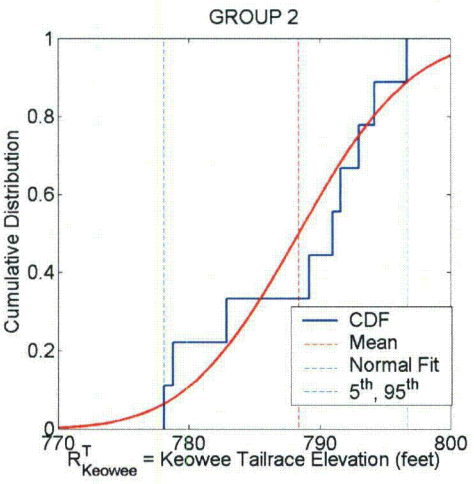


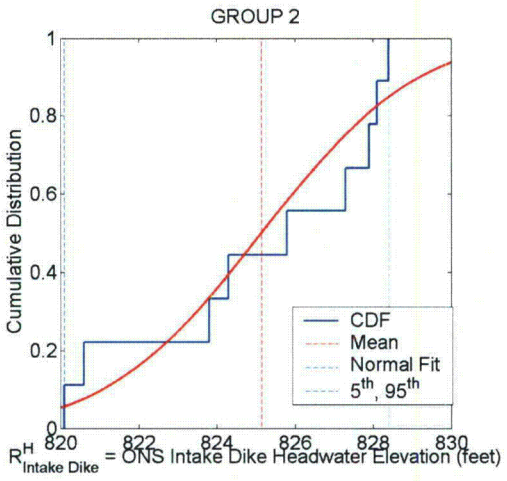
ATTACHMENT B2

GROUP 2 RESULTS



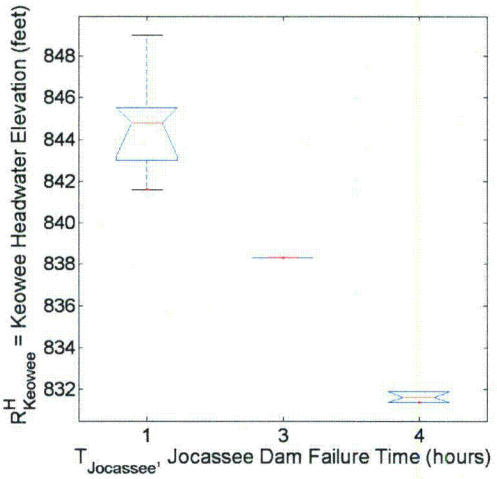




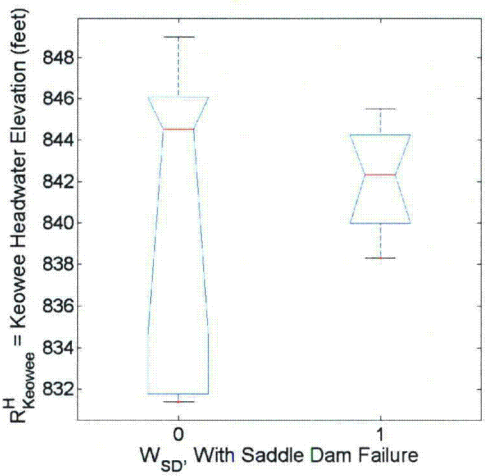


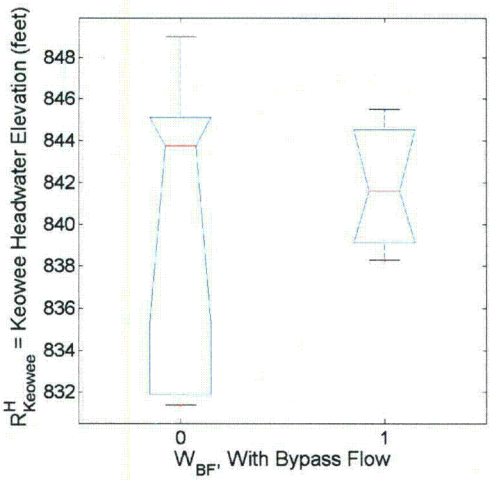
GROUP 2 VARIATION IN KEOWEE HEADWATER ELEVATION DUE TO INDIVIDUAL PARAMETERS

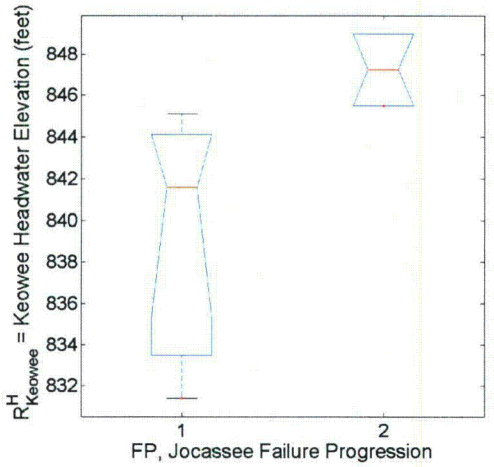
Time to Failure



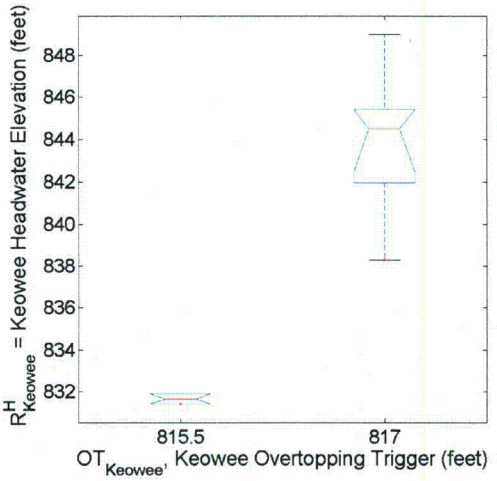
Modeling Parameters



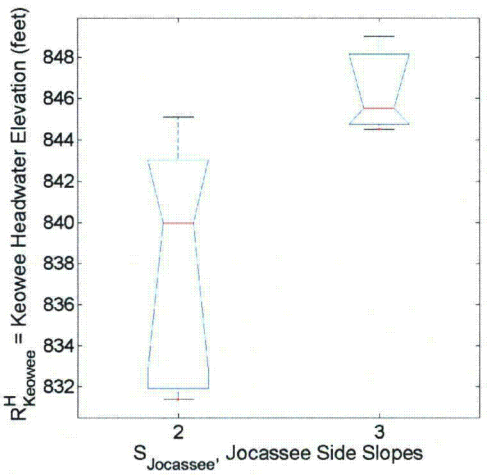


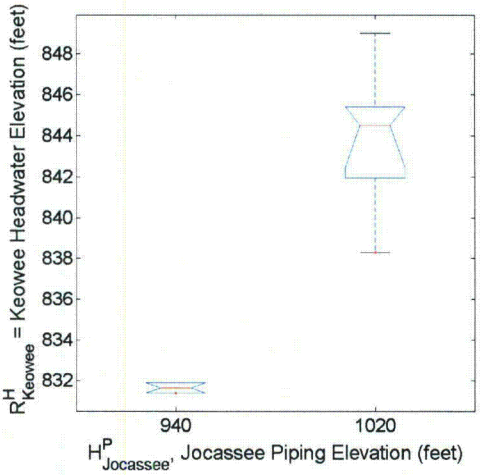


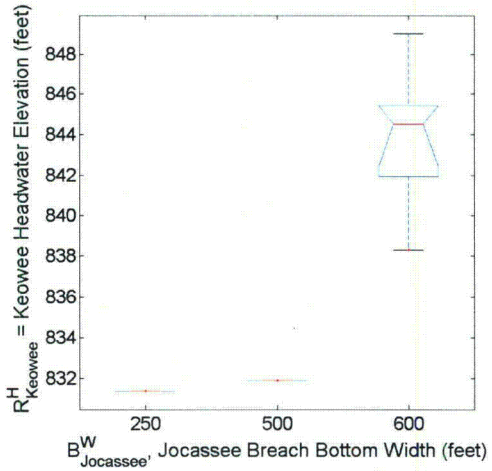
Geometric Parameters (Keowee)



Geometric Parameters (Jocassee)

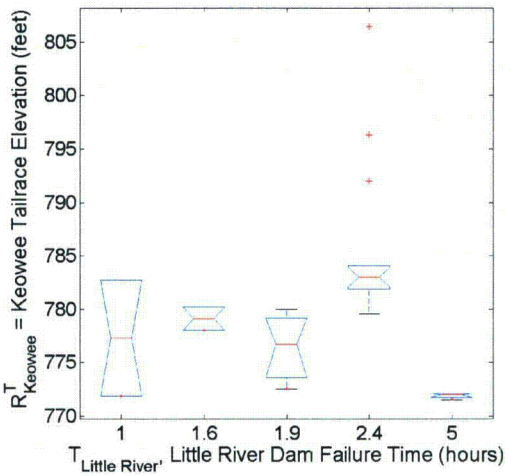


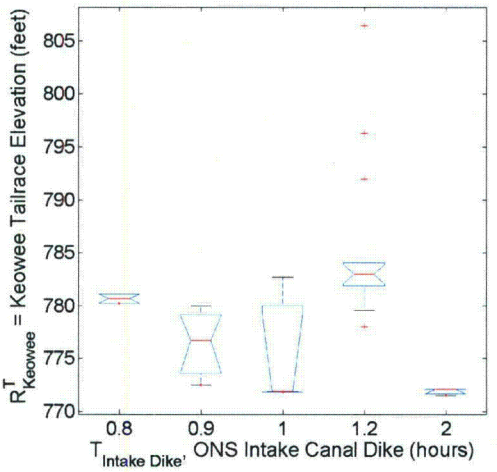


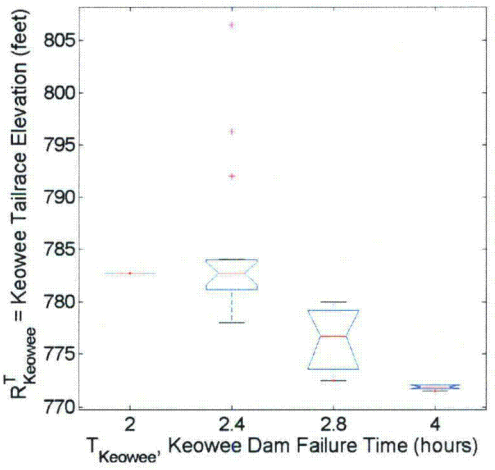


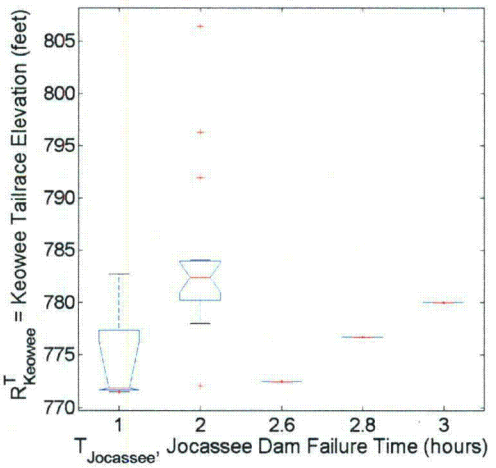
GROUP 2 VARIATION IN KEOWEE TAILRACE ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

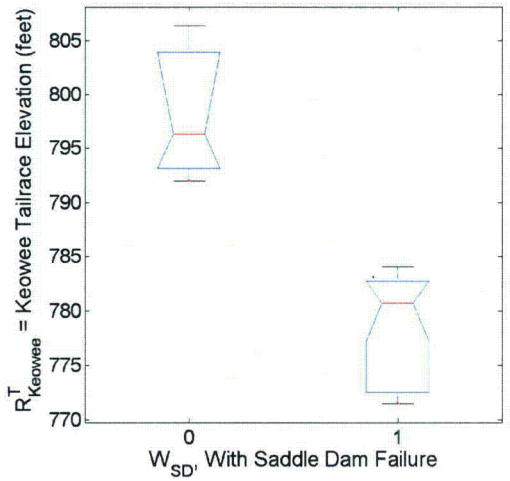




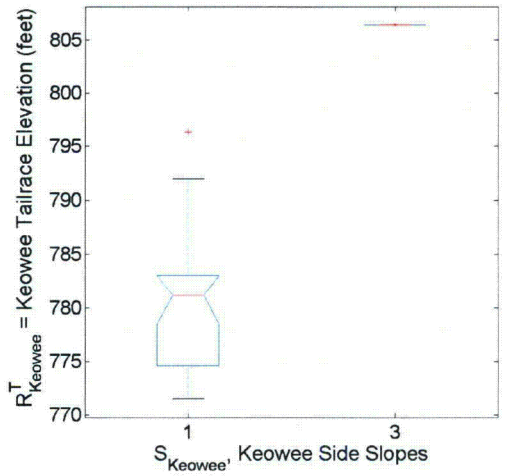


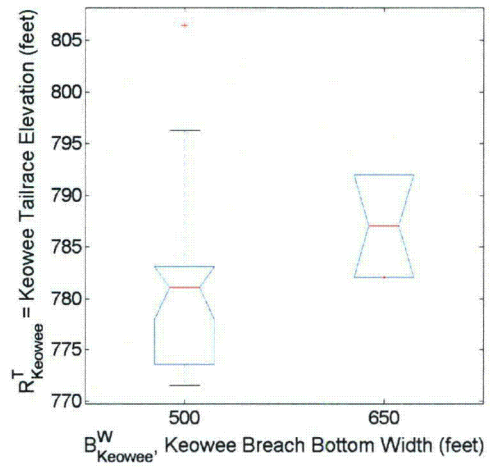


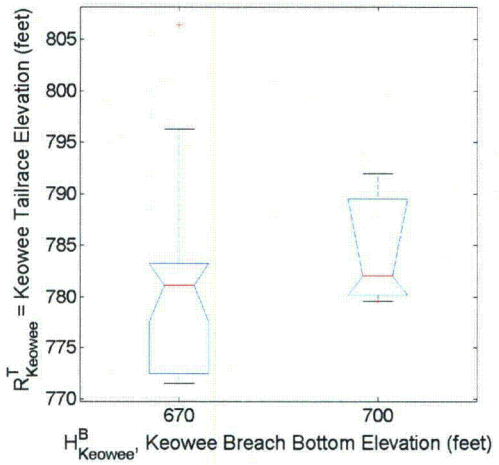
Modeling Parameters



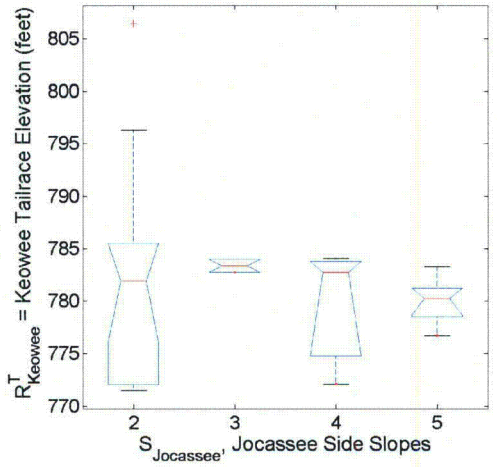
Geometric Parameters (Keowee)

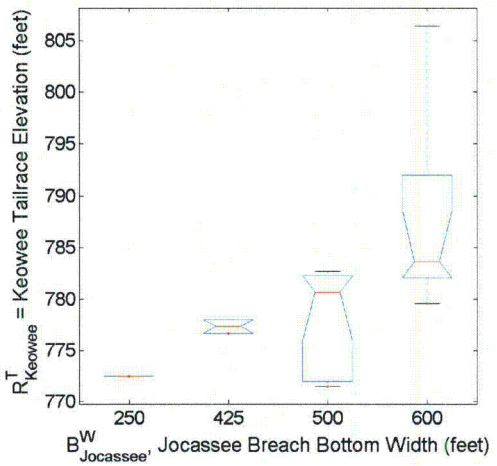






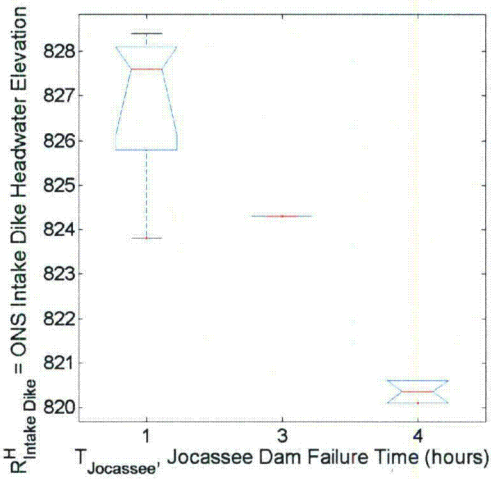
Geometric Parameters (Jocassee)



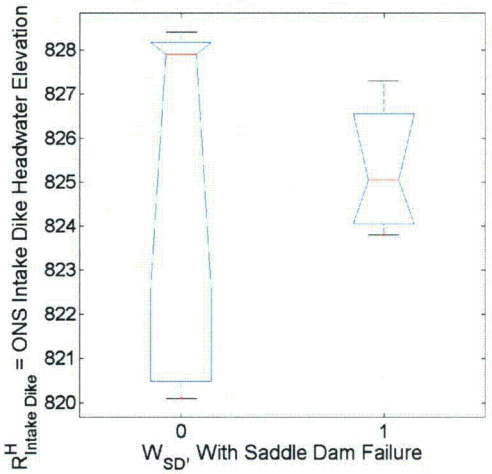


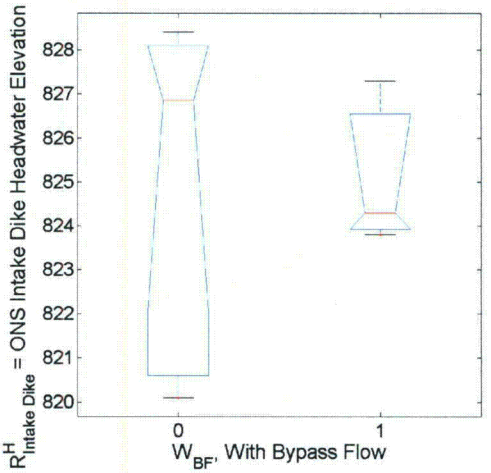
GROUP 2 VARIATION IN ONS INTAKE DIKE HEADWATER DUE TO INDIVIDUAL PARAMETERS

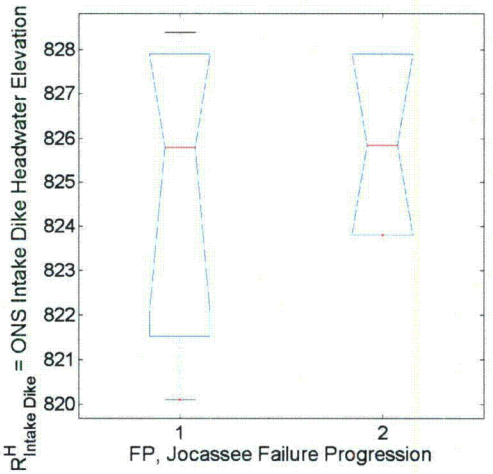
Time to Failure



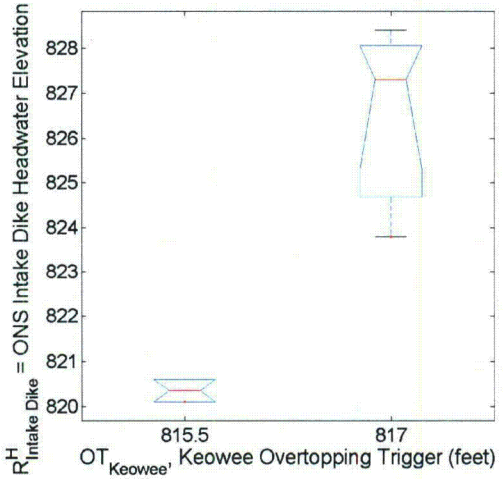
Modeling Parameters



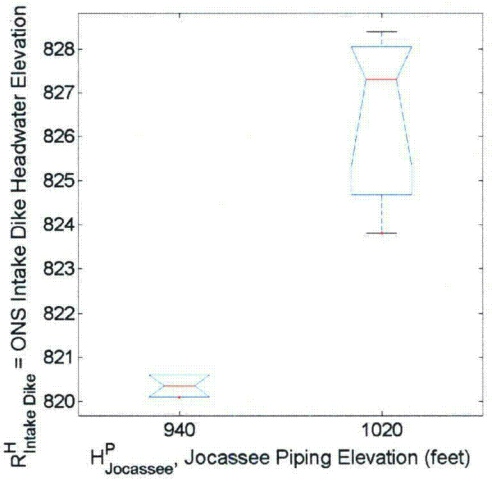


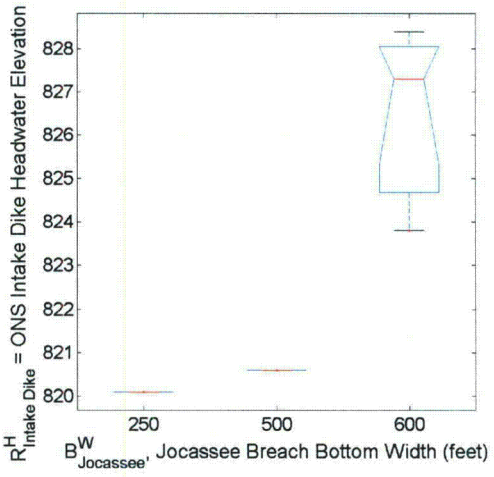


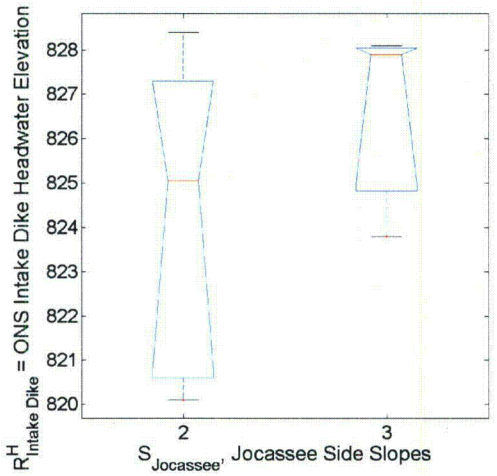
Geometric Parameters (Keowee)



Geometric Parameters (Jocassee)

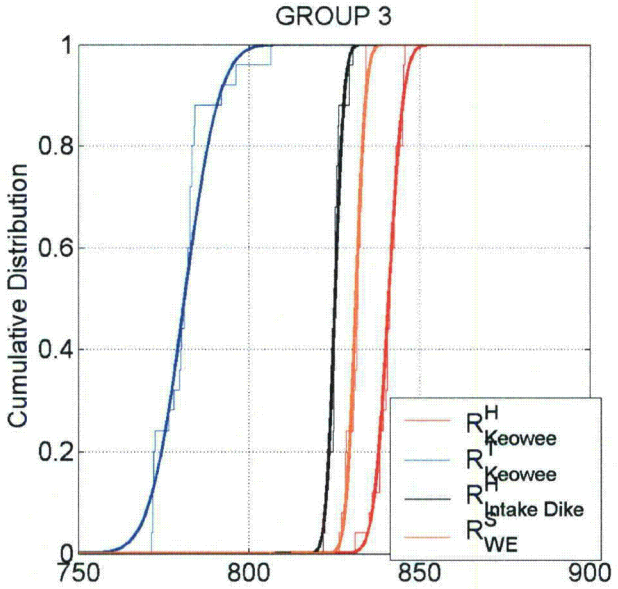


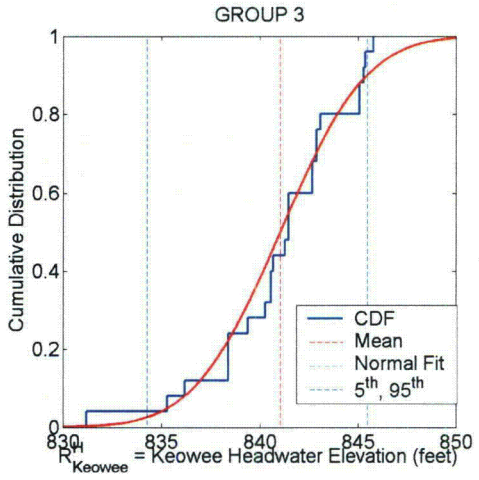


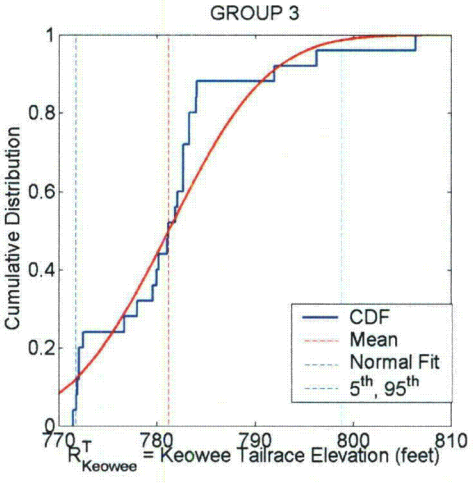


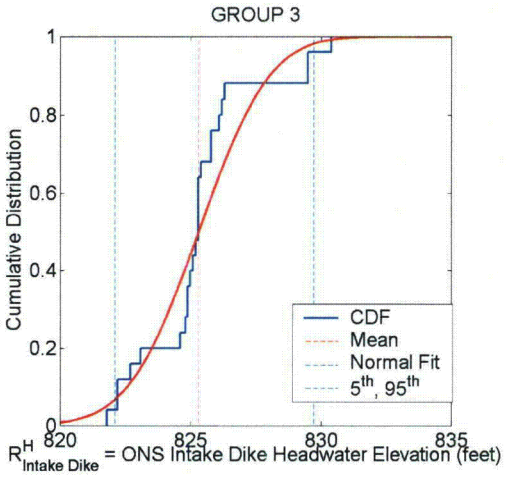
ATTACHMENT C3

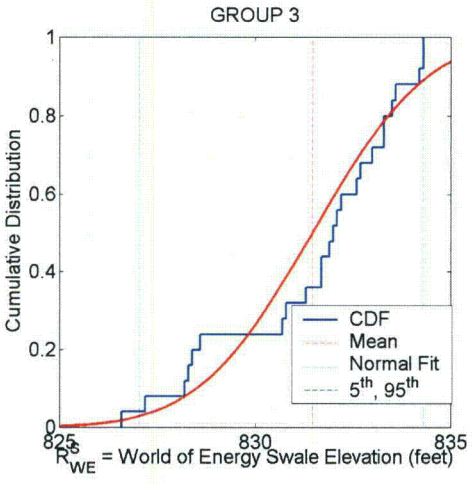
GROUP 3 RESULTS





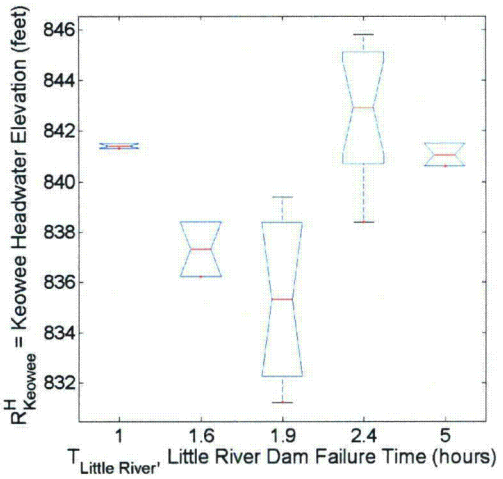


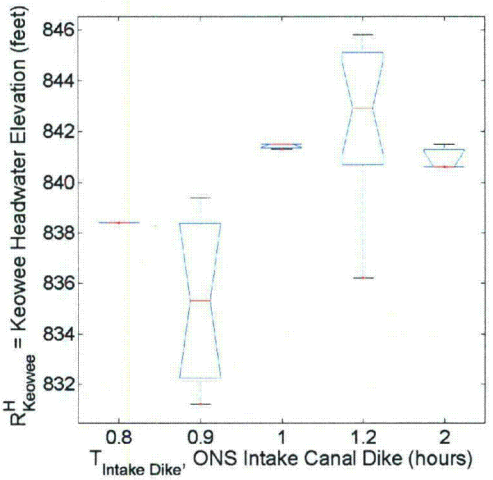


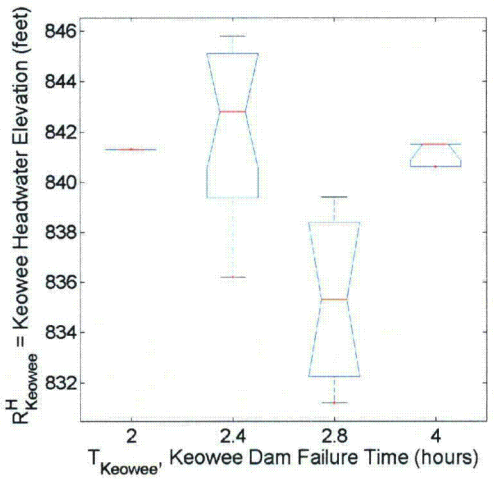


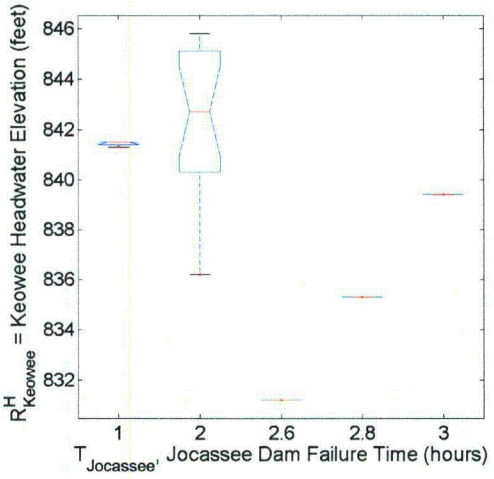
GROUP 3 VARIATION IN KEOWEE HEADWATER ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

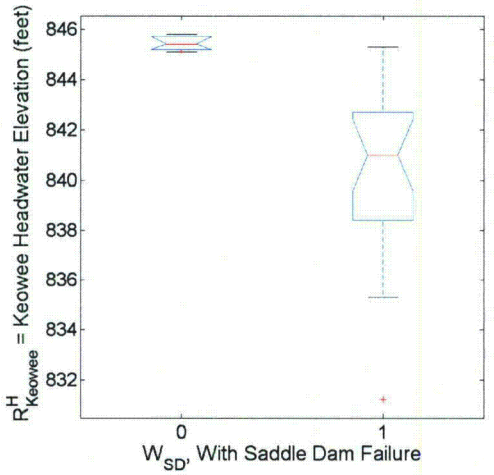




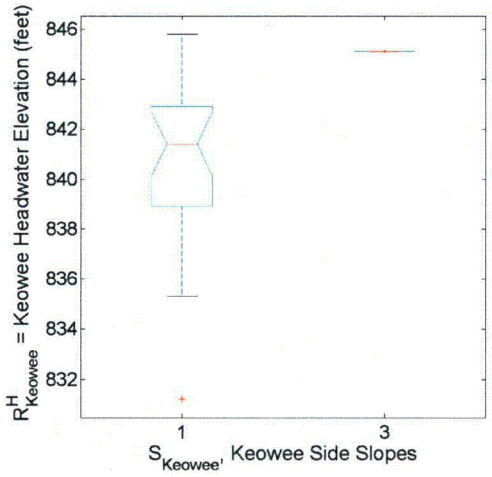


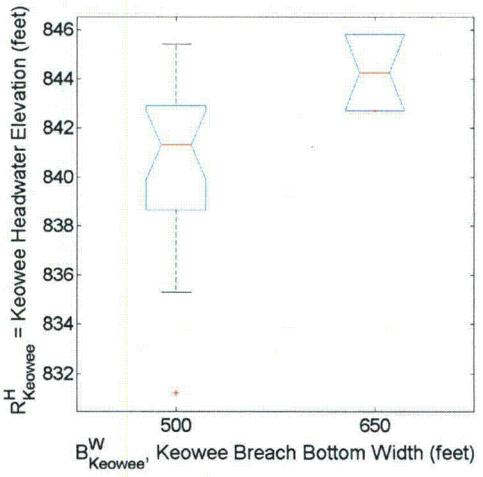


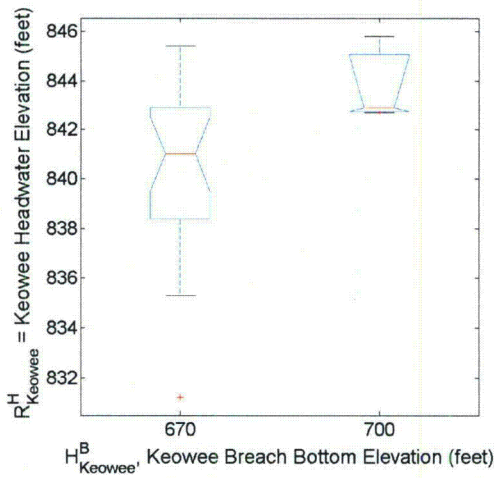
Modeling Parameters



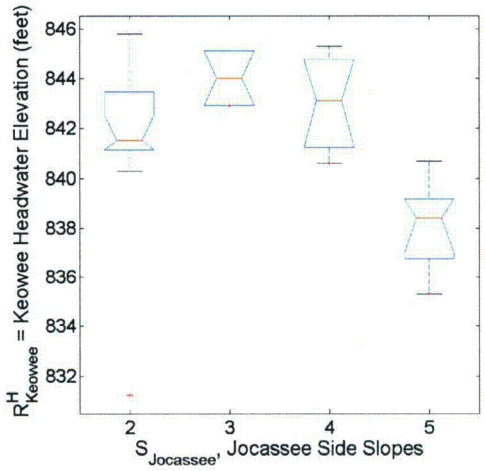
Geometric Parameters (Keowee)

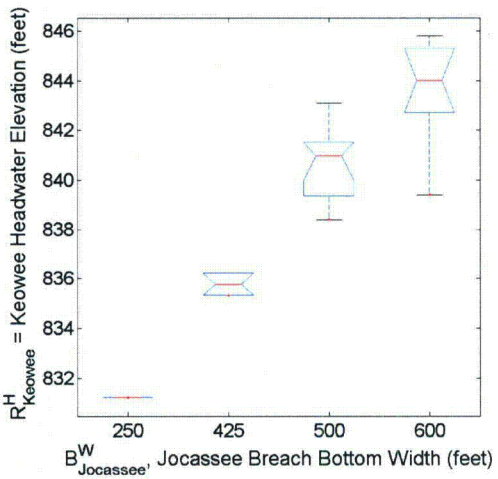






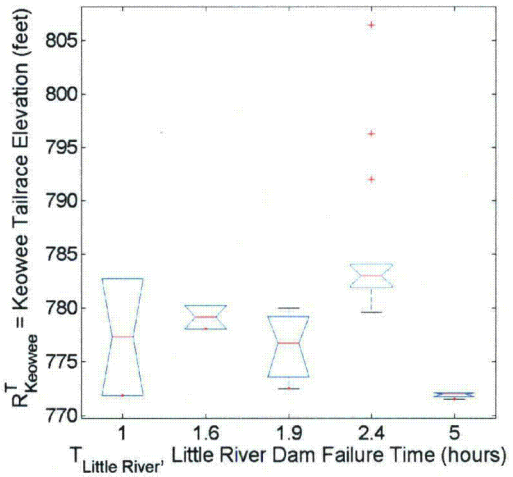
Geometric Parameters (Jocassee)

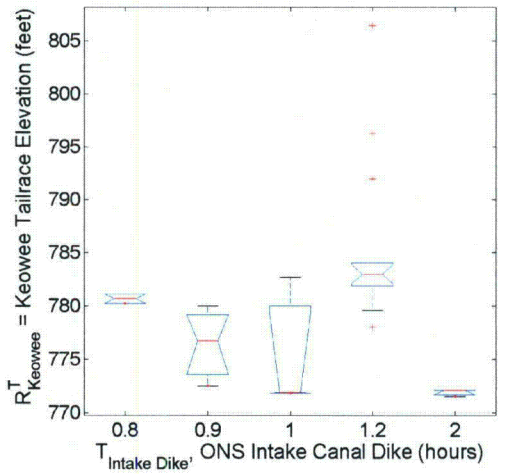


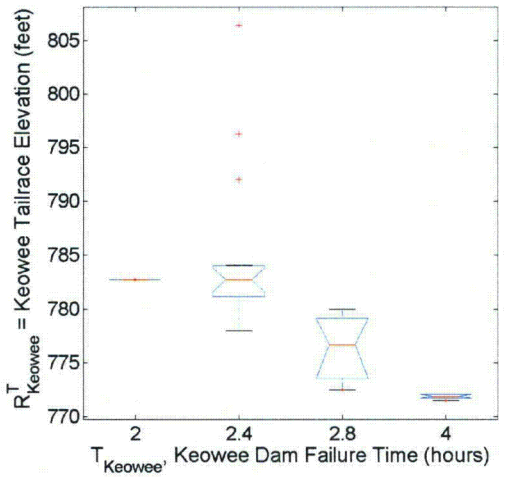


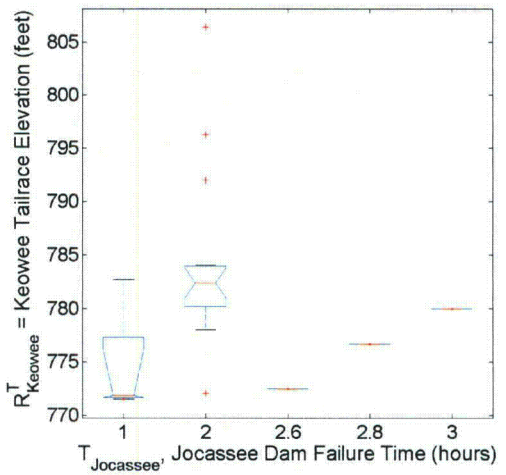
GROUP 3 VARIATION IN KEOWEE TAILRACE ELEVATION DUE TO INDIVIDUAL PARAMETERS

Time to Failure

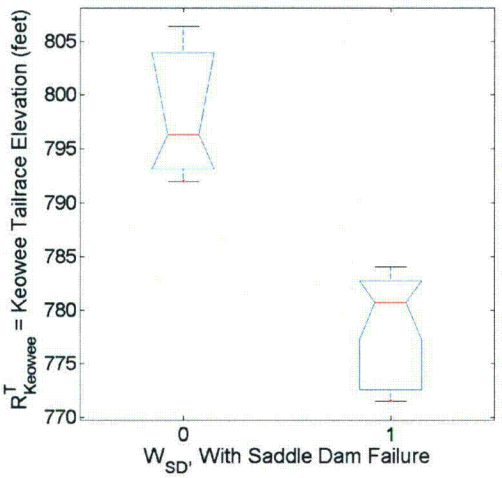




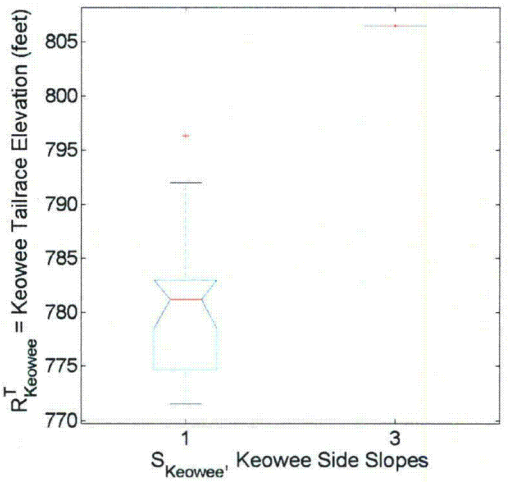


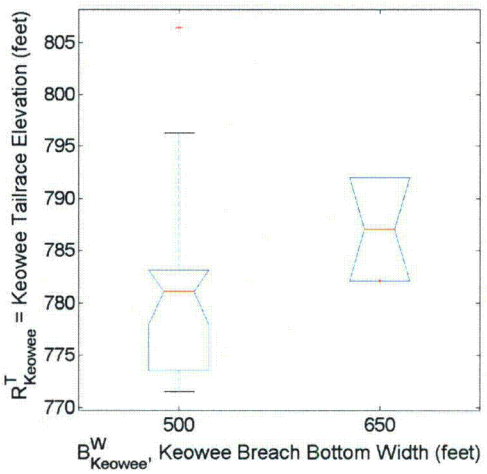


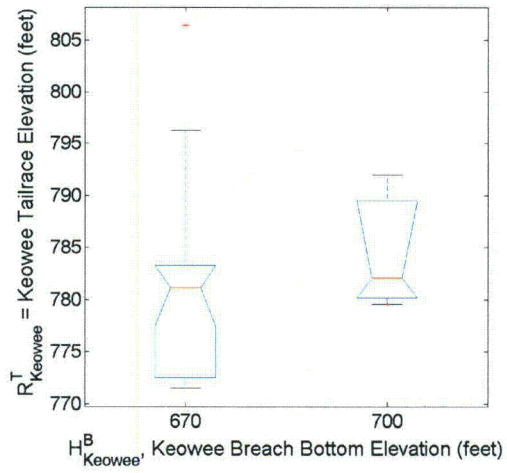
Modeling Parameters



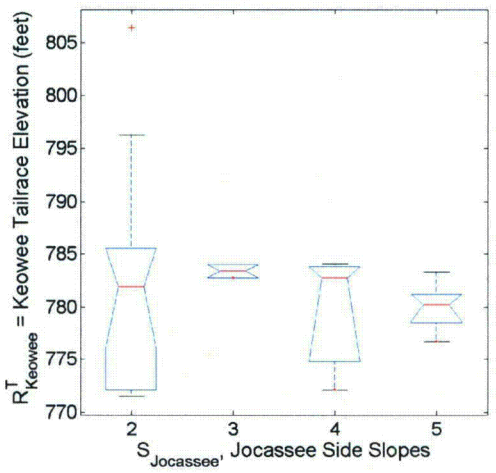
Geometric Parameters (Keowee)

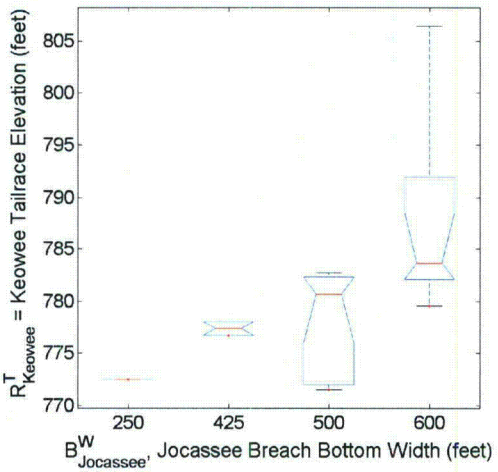






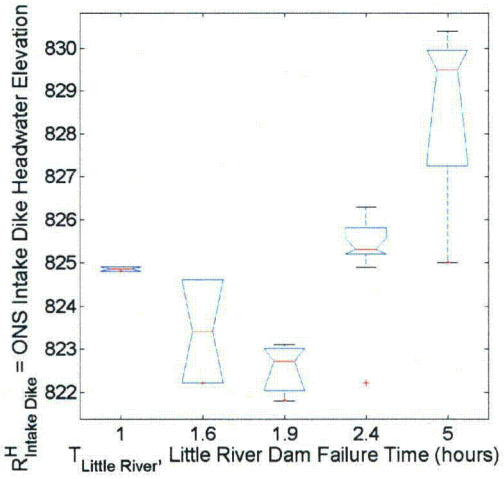
Geometric Parameters (Jocassee)

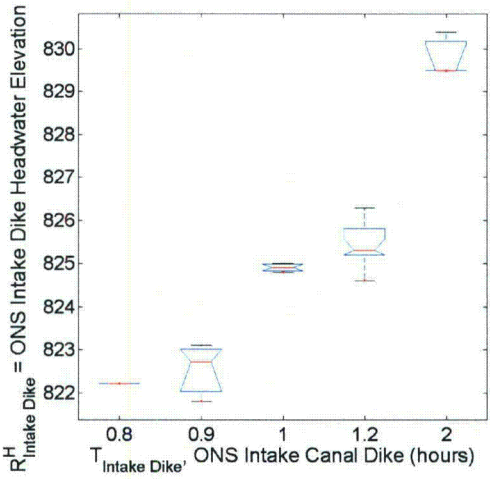


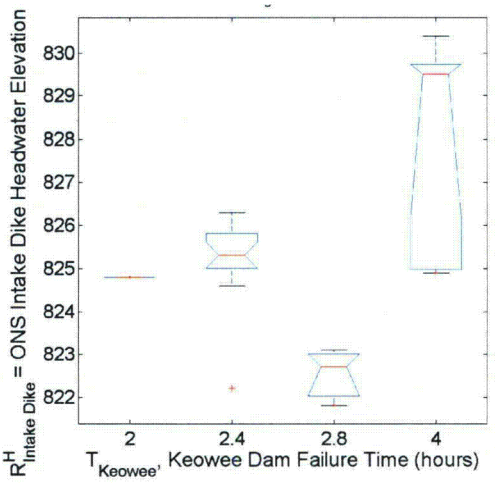


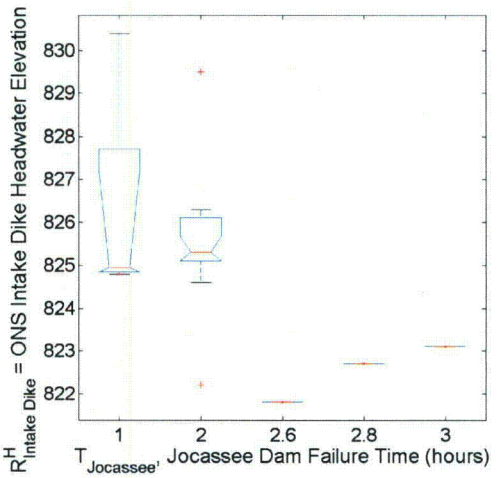
GROUP 3 VARIATION IN ONS INTAKE DIKE HEADWATER DUE TO INDIVIDUAL PARAMETERS

Time to Failure

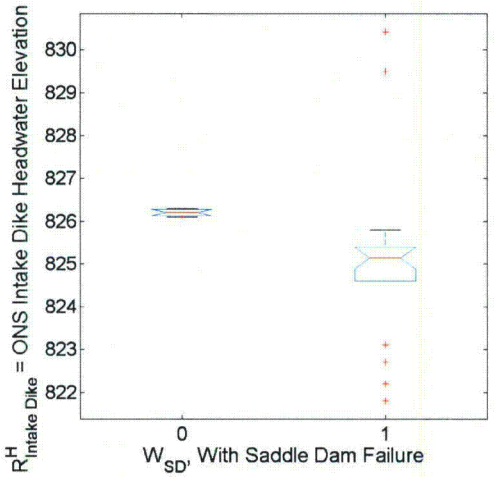




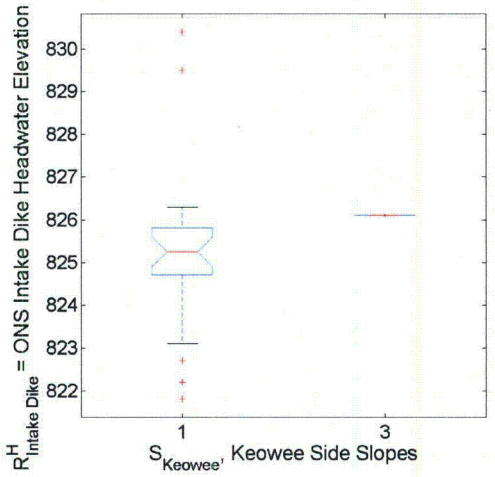


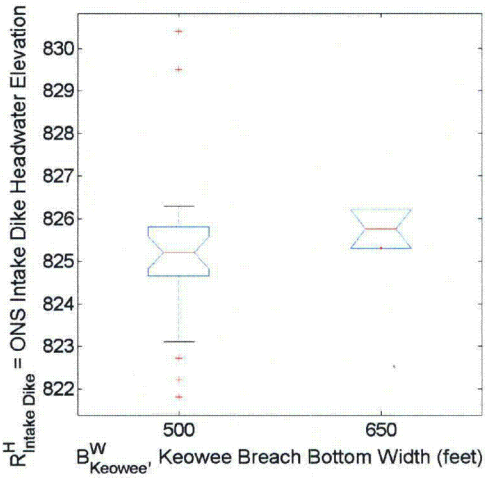


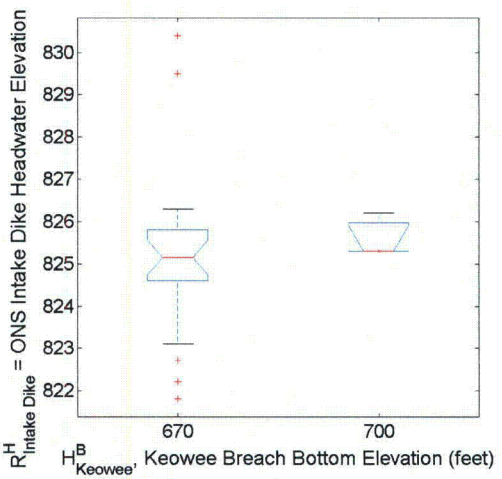
Modeling Parameters



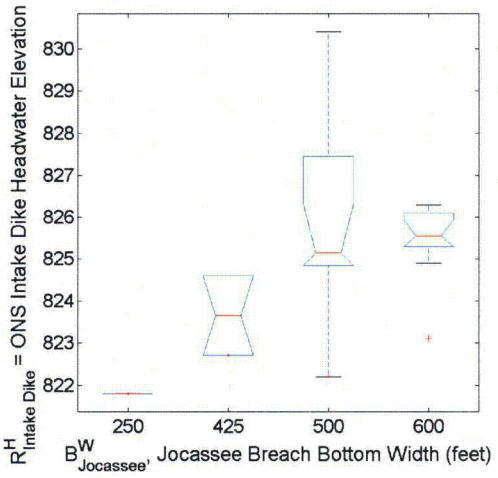
Geometric Parameters (Keowee)

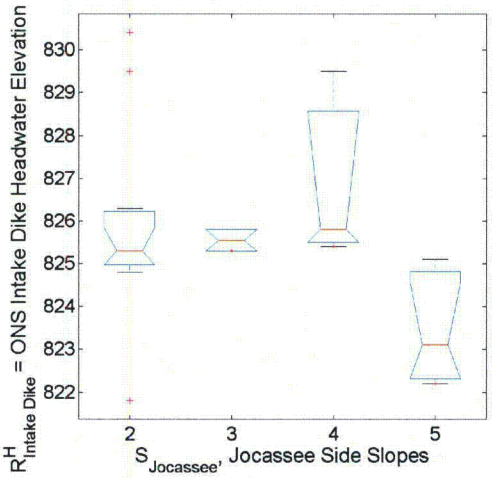


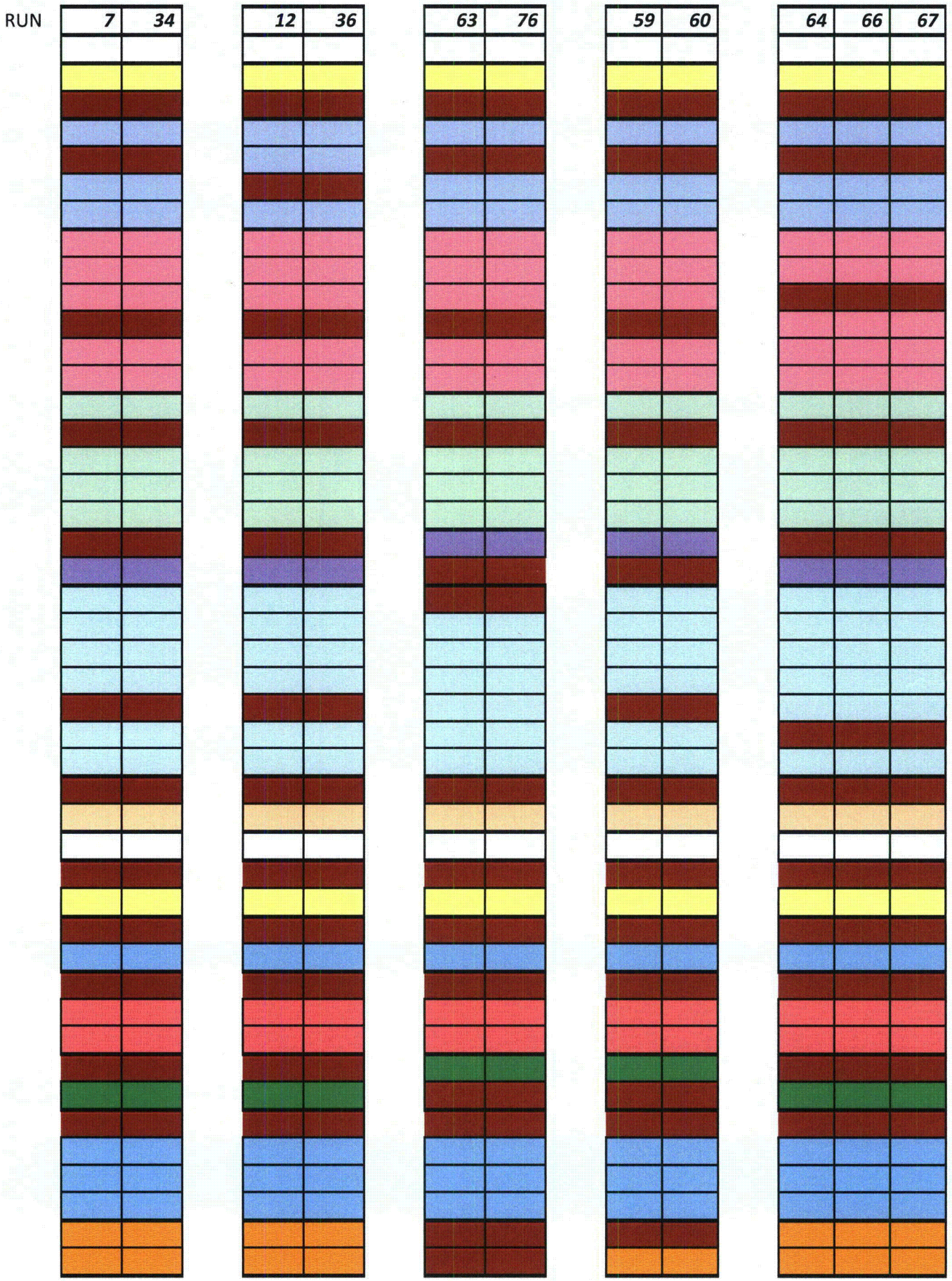


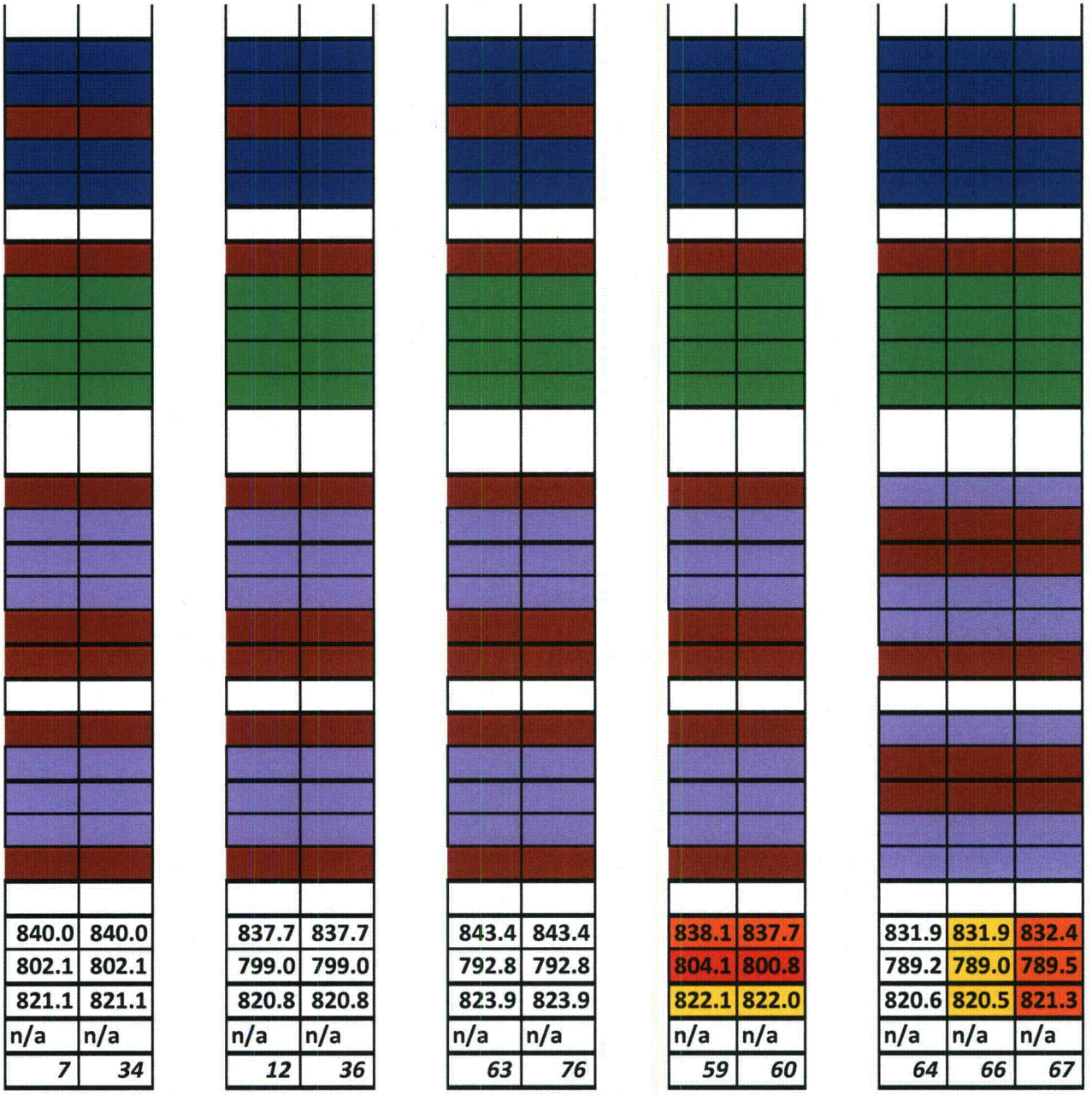


Geometric Parameters (Jocassee)






RUN
7
34
12
36
63
76
59
60
64
66
67



	840.0	840.0		837.7	837.7		843.4	843.4		838.1	837.7		831.9	831.9	832.4
	802.1	802.1		799.0	799.0		792.8	792.8		804.1	800.8		789.2	789.0	789.5
	821.1	821.1		820.8	820.8		823.9	823.9		822.1	822.0		820.6	820.5	821.3
	n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a		n/a	n/a	n/a
RUN	*7*	*34*		*12*	*36*		*63*	*76*		*59*	*60*		*64*	*66*	*67*

INPUT/OUTPUT VALUES EQUIVALENT BETWEEN INDIVIDUAL SETS OF RUNS

INPUT VALUES EQUIVALENT/OUTPUT DIFFERENT BETWEEN RUNS