ENCLOSURE

SEISMIC ANALYSIS

CORRECTIVE ACTION PROGRAM (CAP) PLAN

REVISION 2

WATTS BAR NUCLEAR PLANT

SEISMIC ANALYSIS

CORRECTIVE ACTION PROGRAM PLAN

REVISION 2

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1	As a result of the NRC/TVA February 7-8, 1989 meeting on WBN CAPs, revision 1 was made to extablish criteria for evaluation (Set B) and criteria for new design/modification (the envelope of B and C). (affected pages - ii, 1-24, 26 and 27) Additional Changes were made for clarification purposes. Changes made to this document in this revision are identified with a bar in the right margin of the text.	06-22-89
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SEISMIC ANALYSIS

CORRECTIVE ACTION PROGRAM PLAN

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CORRECTIVE ACTION PROGRAM (CAP) PLAN

1.0 INTRODUCTION

The seismic design basis for Watts Bar Nuclear Plant (WBN) (Reference 1) is the Modified Newmark design spectrum anchored at 0.18 g horizontal and 0.12 g vertical for the Safe Shutdown Earthquake (SSE). The Operating Basis Earthquake (OBE) is equal to one-half the SSE. The design basis spectrum was confirmed to be an acceptable design basis by comparison with the Site Specific Response Spectra developed in 1979. The seismic design basis was documented in the WBN Final Safety Analysis Report (FSAR) and the NRC review and acceptance was documented in the WBN Safety Evaluation Report (SER). (SER is based on FSAR through Amendment 46).

An independent review of the seismic analysis calculations for Seismic Category I structures was initiated in September 1987 as part of the Civil Calculation Activity of the Design Baseline Verification Program. The Civil Calculation Activity is being performed to ensure that essential civil calculations exist, are retrievable, and are technically adequate. The seismic analysis calculations were selected for an early review to ensure that the analysis and the resulting Amplified Response Spectra (ARS) used for seismic design of structures, systems, and components are technically adequate and satisfy licensing requirements.

Based on this review, certain aspects of the structural seismic analysis were identified as requiring further evaluation and justifications.

An area of seismic analysis methodology was also identified from the WBN Employee Concern Program which required additional evaluation. The concern is related to the time interval of integration used for performing seismic analyses. Also, three CAQRs identified issues related to soil properties used in seismic analyses and consideration of soil and pile interaction effects. The employee concern, CAQRs, and their brief descriptions are provided in Attachment 1. The issues identified from the calculation review, employee concern, and CAQRs are tabulated in Table 1.

To complement the calculation review, a comparison of the seismic criteria used in the analysis of structures with the FSAR commitments and SER provisions was initiated in July 1988. The purpose of this activity was to assure that the criteria used in the original seismic analysis of structures are technically adequate and consistent with the licensing requirements. The matrix comparing the seismic analysis criteria, FSAR and SER for Seismic Category I structures is shown in Table 2.

A review of Table 2 indicates that the seismic analysis criteria used in original analysis of WBN structures are consistent with the FSAR and SER. Due to the issues identified in Table 1, an evaluation of several Category I structures is planned to assure that the original seismic analysis of WBN is adequate.

The root cause of the issues identified in this CAP is attributed to the use of engineering judgments in the original seismic analysis without supporting documentation.

2.0 OBJECTIVE

The objectives of this CAP are to ensure that the criteria for and the seismic analysis of Category I structures, including the generation of the structural loads and ARS, are technically adequate and meet licensing requirements. Based on the results of the review thus far, some revisions will be necessary to the design criteria and the FSAR. Licensing commitment changes will be proposed only when technically justified.

3.0 SCOPE

The scope of this CAP includes:

- Review, revision, and augmentation of the seismic analysis criteria used for Category I structures to assure compliance with the licensing requirements.

- Review, revision, and augmentation of seismic calculations for Category I structures as required to resolve the issues identified in this CAP.

- Define the seismic criteria for future evaluations and new designs or modifications of structures, systems, and components.

4.0 DESCRIPTION OF PROGRAM

This CAP consists of the following activities:

- Review of seismic analysis criteria and licensing requirements for Category I structures.

- Review of seismic analysis calculations for Category I structures and revisions as required, or preparation of new calculations when necessary.

- Disposition of identified issues.

- Definition of the seismic criteria for future evaluations and new designs or modifications of structures, systems, and components.

Additionally, recurrence control is addressed and licensing assessment is provided. A flow chart and fragnet for the work are included in Attachments 2 and 3, respectively.

4.1 <u>Review of Seismic Analysis Criteria and Licensing Requirements</u>

The seismic analysis criteria have been reviewed for technical adequacy. The criteria have also been compared with the applicable FSAR and SER sections to ensure that the criteria are consistent with the licensing requirements. For the Category I structures, Table 2 shows the comparison between the original seismic analysis criteria, FSAR commitments, and SER provisions.

As demonstrated by Table 2, the seismic analysis criteria used in the original analysis of WBN structures are consistent with the FSAR requirements and SER provisions. In addition, in view of the current industry practice, a study has been initiated to evaluate the effects of floor vertical flexibility on the design of systems and components.

Table 2 is based on Revision 3 of the seismic design criteria, WB-DC-20-24, which will be revised to include the criteria discussed in Section 4.3.5 of this CAP.

The criteria for seismic analysis of the Additional Diesel Generator Building (ADGB), which was included in Amendment 57 of the FSAR (after the SER was issued), will be deleted and the ADGB will be reanalyzed as discussed in Section 4.3.5.

4.2 Review of Seismic Analysis Calculations

An independent review of the seismic analysis of each Category I structure has recently been performed. The review included the following structures.

- Reactor Building Interior Concrete Structure (ICS).
- Reactor Shield Building (SB).
- Steel Containment Vessel (SCV).
- Auxiliary Control Building (ACB).
- Intake Pumping Station (IPS).
- Diesel Generator Building (DGB).
- Additional Diesel Generator Building (ADGB).
- Refueling Water Storage Tanks (RWST).
- North Steam Valve Room (NSVR).
- Pipe Tunnels
- Waste Packaging Area (WPA).
- Condensate Demineralizer Waste Evaporator Building (CDWE).

The WPA and CDWE contain no safety-related systems or components. They were designed as Category I structures to ensure that they will not impact the adjacent ACB during a seismic event.

Several engineering judgments without supporting documentation were identified during the review of the calculations for the ADGB, DGB, and the CDWE. There are also two CAQRs related to the modeling of the supporting piles in the seismic analysis of the ADGB and CDWE (See Attachment 1). In order to resolve questions related to the engineering judgments and the CAQRs, reanalysis of these structures is being performed as discussed in Section 4.3.2.

The calculation review also identified the need to review the torsional modeling of the ICS, ACB, and NSVR. This issue is being addressed as described in Section 4.3.3.

4.3 Disposition of Identified Issues

Issues have been identified through employee concerns, CAQRs, and review of seismic analysis calculations, criteria, and licensing requirements. These issues deal with the following areas:

- Integration time step used to perform time history analysis.
- Soil properties and soil-structure interaction concerns.
- Torsional modeling of structures.
- Seismic analysis criteria for the Additional Diesel Generator Building (ADGB).

The above issues and the approach to resolve them are discussed in the following sections. The effects of these issues on the analysis of Seismic Category I structures are discussed in Section 4.3.5.

4.3.1 Integration Time Step Used in Time History Analysis

An integration time step of 0.01 second was used in the original time history analysis of structures to generate the ARS. An engineering judgment was made that 0.01 second was adequate for structural analysis and the earthquake records were digitized at 0.01 second. An employee concern identified that this integration time step might be too large and could result in an underestimation of the response of those modes which have frequencies greater than 20 Hz.

Seismic Category 1 structures are being reanalyzed, addressing the integration time interval issue, as discussed in the subsection 4.3.5.5. Evaluation of existing structures, systems and components using the new analysis results will also address the adequacy of integration timestep used in the original analysis. New designs or modifications will be based on new analysis results which incorporate an adequate integration time step in the development of ARS.

4.3.2 Soil Properties and Soil-Structure Interaction Concerns

The value of shear modulus for the crushed stone supporting media used in the analysis of the Diesel Generator Building (DGB) and the Waste Packaging Area (WPA) was identified as a concern in a CAQR. The design value originally used was based on the assumption that in situ geophysical measurements made on other similar materials were suitable for the crushed stone. Later, in situ testing of crushed stone and review of technical literature resulted in a lower shear modulus than the one used in the DGB and WPA analysis.

In order to resolve this issue for the DGB, a new soil-structure interaction (SSI) analysis using the revised shear modulus will be performed.

As stated previously, the WPA does not house any safety-related systems and components and the original analysis predicted conservative internal structural forces. In the original analysis, a decoupled, two-stage SSI analysis was used to determine the seismic response of the structure and the results were conservative. An analysis using the revised shear modulus is being performed to confirm that the gap between the WPA and adjacent ACB is adequate. Preliminary results confirm that there is sufficient gap between the two structures such that they will not impact each other during a seismic event.

The Condensate Demineralizer Waste Evaporator Building (CDWE) and the Additional Diesel Generator Building (ADGB) analyses included engineering judgments related to the modeling of the supporting piles. The engineering judgments were questioned by a CAQR and involved stiffness consideration of pile groups and an assumption of full contact between the building's mat foundation and the underlying soil. These judgments were made to maximize the structural responses and may not have predicted conservative reactions for the piles.

There are no safety-related systems and components in the CDWE. Calculations are being performed to more accurately consider the stiffness of the pile groups and the postulated gap between the slab and soil. Preliminary results confirm that the gap between the buildings is sufficient for seismic separation and the design of the structure and piles is adequate even when a gap is assumed to exist between the slab and soil.

The seismic analysis of the ADGB is addressed in Sections 4.3.4 and 4.3.5.

4.3.3 Torsional Modeling

During the review of the calculations discussed in Section 4.2, two torsional modeling issues identified were the mechanics of modeling eccentric masses and the methodology used in calculating torsional constants for open cross sections.

Modeling of Eccentricities

In the original seismic models, the eccentricity between the center of mass and the center of rigidity was included at each mass point. However, the physical location of the center of rigidity was not incorporated into the model.

The Interior Concrete Structure (ICS) and the Auxiliary Control Building (ACB) are the two structures affected by the issue of modeling of eccentricities. Seismic analysis calculation of these two structures has been performed, taking into account actual location of shear centers.

Torsional Constants

The only two structures with significant open sections, where the issue of the effect of warping on the calculation of the torsional constant becomes important, are the ICS and the North Steam Valve Room (NSVR). In both of these cases the original calculations did not include the warping contribution to torsional stiffnesses and thus the resulting calculated torsional constant was lower. This approach was considered to be conservative since calculated torsional responses would be greater. However, the lower torsional constant can cause shifts in the calculated frequencies of the structure and thus, the shape of the ARS can be affected.

Calculations were performed for the ICS considering the modeling of eccentric masses and the revised torsional constants for open sections. An equivalent stick model was developed from a 3-dimensional finite element model to study the effect of the revised torsional constants. The calculations indicated that further evaluations will be required to justify the adequacy of the original calculations (see Section 4.3.5).

A reanalysis of the NSVR considering torsional constants including the warping contribution will also be performed to evaluate the adequacy of the original calculations.

4.3.4 Seismic Analysis Criteria for the Additional Diesel Generator Building (ADGB)

When the ADGB was added to the WBN design, new criteria for seismic analysis of the ADGB were developed. These criteria were based on the current NRC Standard Review Plans (Revision 1) and Regulatory Guides. These criteria were incorporated in the FSAR by Amendment 57, after the NRC had issued the SER and the supplements. The criteria defined in Amendment 57 will be eliminated and the ADGB will be reanalyzed as discussed in Section 4.3.5. This will bring the criteria for ADGB analysis in line with other Category 1 structures at the plant.

4.3.5 Summary of Seismic Analysis Review for Category I Structures

4.3.5.1 Original Analyses

The original analyses of Category I structures were performed consistent with the FSAR requirements and using methodologies that were prevalent at that time. The criteria used and analytical results were reviewed by the NRC prior to issuance of the SER. The seismic analysis results, in the form of structural loads and floor or amplified response spectra (ARS) were used in the design of structures, systems, and components. The Additional Diesel Generator Building (ADGB) was designed at a later date using a different criteria, added to the FSAR in Amendment 57, which has not been reviewed by the NRC.

The criteria used to perform the original analyses and the significant analysis parameters, called Set A, are shown in Table 3. As can be seen from this table, the original analyses (except for the Additional Diesel Generator Building) utilized four different time-history records. The average of the response spectra of the four time-history records enveloped the Modified Newmark ground response spectrum which was the design basis. The same four records were used in three directions independently. The vertical input was taken as two-thirds of the horizontal. The structural models used in analyses and described in the FSAR were essentially one-dimensional models but included the torsional effects in the direction of excitation.

4.3.5.2 Analyses Using Site Specific Response Spectra

As a result of the issues discussed in Sections 4.3.1 through 4.3.4, it is concluded that reanalysis of some structures is necessary. The intent of the reanalysis is to demonstrate the adequacy of structures, systems, and components considering the effects of the issues identified through the calculation review, employee concern, and CAQR programs. In order to determine the significance of these issues, i.e., whether the existing hardware meets design requirements or whether modifications would be required, the evaluations will be based on criteria compatible with current practices. This will include the Site Specific Response Spectra (SSRS) developed for WBN evaluations which were reviewed and concurred by the NRC in the SER. It will also include soil-structure interaction analysis methods (strain-dependent soil properties and damping) that are consistent with the Standard Review Plan.

The criteria for SSRS analysis and the significant parameters related to the criteria, called Set B, are shown in Table 4.

4.3.5.3 Reanalysis Using the Original Criteria and Current Modeling Techniques

Category I structures will be reanalyzed using the original criteria with modeling improvements, consistent with the current techniques, to develop a new set of response spectra, called Set C. The new analyses will also include soil-structure interaction analysis methods (strain-dependent soil properties and damping) that are consistent with the Standard Review Plan.

The criteria for this reanalysis and the significant analysis parameters are shown in Table 5. Comparison of Tables 3 and 5 indicates that the two sets of criteria are identical except in the area of modeling (including modal and spatial combinations, and SSI methodology) where current practices differ from those used during the original analysis.

4.3.5.4 Use of Results from Various Analyses

In order to assure uniformity of application and correct interpretation of the results generated from various analyses, the following guidelines are established:

Set A Results: Results of Set A analyses (e.g., ARS, forces, and displacements) are the design data of record. Calculations supporting existing structures, systems, and components are based on Set A results. Any new calculations for new design or modifications shall be generated as described later in this section.

ARS from the original analyses are termed Original Spectra.

Set B Results: Results of Set B analyses (e.g., ARS, forces, and displacements) will be used to evaluate adequacy of structures, systems, and components. The evaluations will be performed in accordance with specific CAP requirements such as HAAUP, HVAC, Cable Tray, Conduit, Equipment Seismic, and Instrument Lines. These evaluations can be performed at the spectra level or component level.

ARS from Set B results are termed Evaluation Spectra.

Envelope of Set B and C Results: Results obtained by enveloping the Set B and Set C (e.g., ARS, forces, and displacements) will be used for new designs or modifications. Any class of components or individual items that are not designed using the original seismic design basis i.e., Set A ARS, will require new calculations based on the envelope of Set B and C results.

The envelope of Set B and C ARS are termed New Design or Modification Spectra.

4.3.5.5 Criteria for Evaluation and New Design or Modification of Structures, Systems, and Components

The various structural analyses discussed above and their use are summarized in Table 6 for each structure housing Category I systems and components. The criteria used for original analysis of the Additional Diesel Generator Building will be eliminated. New analysis will be performed to generate Set B and Set C results.

Both Set B and Set C analyses will use the same 3D models, consistent with the SRP. Coupling effects between horizontal and vertical directions will be included. The integration time step will be 0.005 seconds. If frequency domain analysis methods are used, input time-history records will be at 0.01 second intervals. The spectra will be calculated by enveloping the responses at extreme points at each floor level.

The Young's and shear moduli of the concrete have been reevaluated for use in the reanalyses. The evaluation concluded that lower moduli values should be used for Interior Concrete Structure, Additional Diesel Generator Building, and North Steam Valve Room. The revised moduli will be incorporated into both Set B and Set C analysis.

As shown in Table 6 and as discussed in Section 4.3.5.4, evaluation of structures and the systems and components contained in these structures will be based on Set B. For rigorously analyzed piping, the envelope of Set B and C response spectra will be used in the HAAUP program. The scope of evaluations for systems and components are discussed in the other CAPs (Cable Tray, Conduit, HVAC, Instrument Lines, HAAUP, and Equipment Seismic Qualification) in detail. Any new design or modification of structures, systems, and components will be based on the envelope of Set B and C.

The criteria and methodology to be used in the evaluations and new designs or modifications of systems and components are shown in Table 7. As shown in the table, damping values based on Regulatory Guide 1.61, Code Case N411, and applicable test data will be used. Damping values for each commodity are shown in Table 8. Use of higher damping is justified since the evaluation criteria (Set B) are consistent with the SRP provisions. The new design or modification criteria (envelope of Set B and C) is more conservative than the evaluation criteria and, therefore, use of higher damping values is appropriate for this case also.

The analysis techniques to be used for system and component analysis in the new work are also consistent with the SRP provisions. Equivalent static, response spectrum, and time-history analysis methods will be used. The time-history analysis may be used if the system input time-history records are demonstrated to contain sufficient energy over the entire frequency range by an analysis of its power spectral density. Uncertainties in T-H analysis will be addressed through the use of peak shifting technique.

In the evaluation and design of systems, and components except piping the 2D absolute sum method will continue to be used. This is consistent with the FSAR requirements. Studies show that the difference resulting from the use of 2D absolute sum and 3D square-root-of-sum-of-squares is small and, therefore, use of the 2D absolute sum method for maintaining the licensing basis and continuity is acceptable. For piping analysis, the 3D SRSS approach will be used, as indicated in Table 7 in order to be able to use N411 damping values.

In summary, the seismic criteria for systems and components as shown in Tables 7 and 8, when used in conjunction with ARS from the new analyses, will provide assurance that WBN plant will have been designed to meet licensing requirements and to be consistent with the current SRP provisions.

4.4 Recurrence Control

The root cause identified in this CAP has been addressed through procedural improvement.

A procedure is now in place (NEP 3.1) to ensure that engineering judgments used in the design process will be adequately documented.

4.5 Licensing Assessment

In order to resolve the issues identified in this CAP and to establish the seismic design basis for future work, revisions to the design criteria and FSAR may be necessary. Any changes to the licensing commitments will be proposed only when technically justified.

5.0 PROGRAM INTERFACES

The ARS are used in the design of safety-related systems and components. Therefore, the output of this CAP will provide input to other CAPs such as HAAUP, Cable Trays, Conduit, Instrument Lines, HVAC, and Equipment Seismic Qualification.

6.0 PROGRAM IMPLEMENTATION

Nuclear Engineering (NE) is the lead organization for implementing and completing the Seismic Analysis CAP. Calculations will be performed in accordance with standard TVA procedures and practices.

7.0 PROGRAM DOCUMENTATION

Results of this CAP will be documented in design criteria, calculations and reports. The FSAR revisions resulting from this CAP will be submitted to the NRC. Affected documents will be revised in accordance with NE procedures. A final report will be prepared documenting the results of evaluations performed to resolve identified issues.

8.0 CONCLUSION

The completion of the Seismic Analysis CAP will confirm that the seismic analysis of structures and the ARS generated from the analyses are technically adequate and satisfy licensing requirements. In addition, related employee concern and CAQRs dealing with seismic analysis issues will be resolved.

9.0 REFERENCE

1. Dynamic Earthquake Analysis of Category I Structures and Earth Embankments, WB-DC-20-24, Revision 3, July 1988

TABLE 1

Issues Identified from Review of Seismic Analysis Calculations of Category I Structures, Employee Concerns, and CAQRs.

Issue	Disposition
1. Integration time step used to perform time history analysis. (ECP-87-KX-009-01)	New analyses will be performed using a time step of 0.005 seconds. When frequency domain analysis is used, a time step of 0.01 seconds will be used. (See Section 4.3.1)
2. Dynamic soil properties and soil-structure interaction concerns (CAQR WBF 870038R1, CAQR WBF 870039R1, and CAQR WBP 870396R0)	
° Waste Packaging Area and Condensate Demineralizer Waste Evaporator Building	° Calculations are being completed and preliminary evaluation shows the adequacy of existing analyses.
° Diesel Generator Building and Additional Diesel Generator Building	° Further analyses will be performed to evaluate structures and components.
3. Torsional modeling	
° Reactor Building Interior Concrete Structure.	° New analyses are being performed to develop ARS which will be used to evaluate structures and components.
° North Steam Valve Room.	° New analyses will be performed to evaluate structures and components.
° Auxiliary Control Building.	° New analysis will be performed to evaluate structures and components.

TABLE 2
COMPARISON OF SEISMIC ANALYSIS CRITERIA, FSAR, AND SER
FOR SEISMIC CATEGORY I STRUCTURES

ATTRIBUTE	DESIGN CRITERIA (DC)[1,2] WB-DC-20-24, Rev. 3	FSAR	SER	DIFFERENCES BETWEEN DC AND FSAR, SER
DYNAMIC ANALYSIS PARAMETERS				
Design Response Spectra (input ground motion spectra)	° Modified Newmark	° Same [3] (2.5.2.6) (2.5.2.7) (3.7.1.1.1)	° Same [4] (2.5.2.1) (3.7.1)	° None - Design basis has been accepted by NRC based on site specific spectra evaluation
Max. top-of-rock accelerations SSE: OBE:	° 0.18 gH, 0.12gV ° 0.09gH, 0.06gV (3.1)	° Same [5] (2.5) (3.7.1.1.1)	° Same (2.5) (3.7.1)	° None
Ratio of vertical to horizontal response spectrum	° 2/3 (3.1) (3.2.1.2)	° Same (3.7.1.1.1) (3.7.2.4.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.1.	° None
Design time histories (input ground motion T-H)	° 4 artificial E/Q's ° The same 4 T-Hs are used in all 3 directions Independently.	° Same (3.7.1.2.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2.	° None

Notes:

(1) This Column indicates design criteria provisions. If no explicit statement is included in DC, the column indicates the actual methodology adopted in analysis.
(2) Basis of comparisons is revision 3 of WB-DC-20-24. Design criteria will be revised to include the criteria for evaluation and new design or modification of structures, systems, and components discussed in Section 4.3.5 of this CAP.
(3) FSAR provision same as DC. (Typical for FSAR column.)
(4) SER agrees with FSAR. (Typical for SER column.)
(5) Due to a typo, the FSAR in Section 3.7.1.1.1 states that the OBE horizontal acceleration is 0.08g, not 0.09g and that the OBE vertical acceleration is 0.6g, not 0.06g.

TABLE 2
COMPARISON OF SEISMIC ANALYSIS CRITERIA, FSAR, AND SER
FOR SEISMIC CATEGORY I STRUCTURES

ATTRIBUTE	DESIGN CRITERIA (DC) WB-DC-20-24, Rev. 3	FSAR	SER	DIFFERENCES BETWEEN DC AND FSAR, SER
Frequency (period) interval for generating ground motion input spectra	° Calculated at 55 periods (Table 6)	° Table does not cover period range .03 to .05 sec. (Table 3.7-1)	° No explicit statement. Concurrence with FSAR is implicit per Section 3.7.2	° Minor differences – FSAR will be updated
Damping values	° FSAR Table 3.7-2A	° Same (Table 3.7-2A)	° Same (3.7.1)	° None
Supporting media	° Shear wave velocity and embedment and overburden depths are defined	° Same (Table 3.7-3) (3.7.1.4)	° No explicit statement. Concurrence with FSAR is implicit per Section 3.7.2.	° None
DYNAMIC ANALYSIS METHODS				
Analysis method	° Time-history modal analysis using four artificial earthquake records for generation of ARS and Response Spectrum Analysis (RSA) for structural loads (3.2.1)	° Same (3.7.2.1)	° Same (3.7.2)	° None
	° Integration time step 0.01 sec	° Same (3.7.2.5.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2.	° None – However adequacy of time step has been addressed.

TABLE 2
COMPARISON OF SEISMIC ANALYSIS CRITERIA, FSAR, AND SER
FOR SEISMIC CATEGORY I STRUCTURES

ATTRIBUTE	DESIGN CRITERIA (DC) WB-DC-20-24, Rev. 3	FSAR	SER	DIFFERENCES BETWEEN DC AND FSAR, SER
Soil-structure interaction	° Rock-Supported Fixed base (allows linear springs which indicate fixed base)	° Same (3.7.2.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2.	° None
	° Soil-Supported Rock motion amplified through soil by linear shear beam w/10% soil damping. Soil modulus was varied. Structures modeled with linear soil springs with 10% damping.	° Same (3.7.2.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2.	° None - However, dynamic soil properties and SSI for some structures are under review.
	° Half-space analysis except for ADGB and RWST which used FLUSH.	° Same (3.7.2.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2. ADGB analysis is not addressed in SER.	° None - However, dynamic soil properties and SSI for some structures are under review.
Torsional, rocking, and translational responses	° Rocking and translation considered. Torsional response taken into account where significant.	° Same (3.7.2.1)	° Torsional responses were considered (3.7.2). Concurrence with treatment of rocking and translation is implicit per section 3.7.2.	° None

TABLE 2
COMPARISON OF SEISMIC ANALYSIS CRITERIA, FSAR, AND SER
FOR SEISMIC CATEGORY I STRUCTURES

ATTRIBUTE	DESIGN CRITERIA (DC) WB-DC-20-24, Rev. 3	FSAR	SER	DIFFERENCES BETWEEN DC AND FSAR, SER
Methods to account for torsional effects	° Lumped-mass models considered eccentricities between center of rigidity and center of mass ° Responses calculated at extreme points.	° Same (3.7.2.11)	° Torsional effects were considered. (3.7.2)	° None
Adequate number of masses	° Based on judgment. Mass points were located at floor slabs, change to geometry, and at intermediate points.	° Same (3.7.2.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2.	° None
Adequate number of modes to assure participation of significant modes	° Response to be calculated using all significant modes (3.2.1)	° Same (3.7.2.1) Modes considered are shown in tables.	° No explicit statement. Concurrence with FSAR is implicit per Section 3.7.2.	° None
Maximum relative displacements between structures	° Maximum relative displacements were calculated by sum of the absolute values	° Same (3.7.3.8.4)	° No explicit statement. Concurrence with treatment of support motions is implicit in Section 3.7.3.	° None
Acceleration time history or response spectra at floors	° Response spectra generated at ground level, at all major floors, and at other points where input is needed for further analysis (3.2.2).	° Same (3.7.2.5.1)	° No explicit statement. Concurrence with FSAR is implicit in Section 3.7.2.	° None

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COMPARISON OF SEISMIC ANALYSIS CRITERIA, FSAR, AND SER
FOR SEISMIC CATEGORY I STRUCTURES

ATTRIBUTE	DESIGN CRITERIA (DC) WB-DC-20-24, Rev. 3	FSAR	SER	DIFFERENCES BETWEEN DC AND FSAR, SER
ANALYTICAL MODELING				
Decoupling criteria for subsystems	° No explicit statement for decoupling. Subsystems were considered rigid in analysis.	° Same (3.7.2.3).	° No explicit statement. Concurrence with FSAR is implicit per Section 3.7.2.	° None
Modeling for three components of input motion	° Three components of input motion were considered. However, no coupling of horizontal and vertical analyses (3.2.1).	° Same (3.7.2.1)	° No explicit statement. Concurrence with FSAR is implicit per section 3.7.2.	° None
DEVELOPMENT OF FLOOR RESPONSE SPECTRA	° Fixed and variable (N411) Damping (2) ° Spectra broadened by ± 10% ° Optional use of ASME Code Case N-397 for peak shifting (2) ° Torsion calc at extreme edges	° Same (3.7.2.9)	° Development of floor response spectra was reviewed (3.7.2).	° Minor differences in period range. FSAR will be updated.
	° Spectra was computed for 55 periods given in Table 6 and at significant periods of the structure and at structural periods shifted by fine interval. ° Vertical spectra generated using wall stiffnesses and vertical input motion only.(1) (3.2.2)	° Table does not cover period range .03 to .05 sec (Table 3.7-1)		

Note:

(1) A study is being performed to evaluate the effects of floor vertical flexibility on systems and components.
(2) Added after SER.

TABLE 2
COMPARISON OF SEISMIC ANALYSIS CRITERIA, FSAR, AND SER
FOR SEISMIC CATEGORY I STRUCTURES

ATTRIBUTE	DESIGN CRITERIA (DC) WB-DC-20-24, Rev. 3	FSAR	SER	DIFFERENCES BETWEEN DC AND FSAR, SER
THREE COMPONENTS OF EARTHQUAKE MOTION	° Critical horizontal responses combined with vertical by ABSUM.	° Same (3.7.2.10.1.1)	° Same (3.7.3)	° None
COMBINATION OF MODAL RESPONSES	° Modes combined by SRSS. Closely spaced modes by the grouping method in RG 1.92.	° Same (3.7.2.7.1.1)	° Same (3.7.2)	° None
INTERACTION OF NON-CAT I WITH CAT I STRUCTURES	° Need to consider interaction of non-Cat I with Cat I structures.	° Same (3.7.2.8)	° Same (3.7.2)	° None
USE OF EQUIVALENT STATIC FACTORS	° Vertical ARS were developed considering structural amplification	° Same (3.7.2.10.1.1)	° Same (3.7.2)	° None
COMPARISON OF RESPONSES	° Results for response spectra and time history analysis of ICS provided in FSAR Figure 3.7-38.	° Same (3.7.2.12) (Figure 3.7-38)	° No explicit statement. Concurrence with FSAR is implicit per Section 3.7.2.	° None
COMPOSITE MODAL DAMPING	° For rock-supported structures, no need to consider composite modal damping. ° For soil-supported structures, modal damping was limited to 10%.	° Same (3.7.2.15)	° No explicit statement. Concurrence with FSAR is implicit per Section 3.7.2.	° None
STRUCTURE OVERTURNING MOMENTS	° Structure overturning moments were calculated for critical horizontal response combined with vertical.	° Same (3.7.2.14.1)	° Same Stability against overturning was considered. (3.7.2)	° None

Table 3. Original Seismic Analysis Criteria for Category I structures - Set A

Attributes	Criteria		
Design Spectra	Modified Newmark		
Peak Ground Accel. SSE	0.18 G Hor. 0.12 G Vert.		
OBE	0.09 G Hor. 0.06 G Vert.		
Artificial Time - History Records	Four artificial T-H records - Use average of four responses. Same four used in each direction independently. Average of T-H spectra envelop modified Newmark.		
Structural Models	As described in the FSAR		
Integration Time Step	0.01 second		
Modal Combination	RG 1.92 (No coupling between directions per FSAR models)		
Spatial Combination for ARS Generation	As described in FSAR (No coupling between directions)		
SSI Methodology	As described in FSAR (see Table 2)		
Peak Broadening	± 10%		
Damping		OBE	SSE
Steel Containment Vessel (SCV)		1	1
Shield Build. and Interior Conc. Struct.		2	5
Other Concrete Structures		5	5
Other Welded Steel Structures		2	2

Table 4. Site Specific Response Spectra (SSRS) Analysis Criteria for Category I Structures - Set B

Attributes	Criteria		
Design Spectra	SSRS		
Peak Ground Accel.			
SSE	0.215 G Hor. 0.15 G Vert.		
OBE	0.09 G Hor. 0.06 G Vert.		
Artificial Time - History Records (1)	Three statistically independent records - one for each direction. T-H spectra envelop SSRS		
Structural Models	3D - Coupling effects included		
Integration Time Step (2)	0.005 second		
Modal Combination	RG 1.92		
Spatial Combination for ARS Generation	3D SRSS or simultaneous input		
SSI Methodology	Elastic Half-Space or Finite Element Approach with strain-dependent soil properties and damping		
Peak Broadening	± 15%		
Damping		OBE	SSE
Welded Steel Structures		2	4
Concrete Structures (3)		4	7

(1) In performing T-H analysis with single set of T-Hs, adequacy of energy content shall be demonstrated.

(2) If frequency domain analysis method is used, input time-history interval of 0.01 second is adequate.

(3) Includes Interior Concrete Structure, Shield, Auxiliary Control, Diesel and Additional Diesel Generator buildings, North Steam VAlve Room, and Intake Pumping Station.

Table 5. Seismic Reanalysis Using Original Criteria and Current Modeling Techniques for Category I structures - Set C

Attributes	Criteria		
Design Spectra	Modified Newmark		
Peak Ground Accel.			
SSE	0.18 G Hor. 0.12 G Vert.		
OBE	0.09 G Hor. 0.06 G Vert.		
Artificial Time - History Records	Four artificial T-H records - Use average of four responses. Same four used in each direction independently. Average of T-H spectra envelop modified Newmark.		
Structural Models	3D - Coupling effects included		
Integration Time Step (1)	0.005 second		
Modal Combination	RG 1.92		
Spatial Combination for ARS Generation	3D SRSS		
SSI Methodology	Elastic Half-space or Finite Element Approach with strain-dependent Soil properties and damping		
Peak Broadening	± 10%		
Damping		OBE	SSE
Steel Containment Vessel (SCV)		1	1
Shield Build. and Interior Conc. Struct.		2	5
Other Concrete Structures		5	5
Other Welded Steel Structures		2	2

(1) If frequency domain analysis method is used, input time-history interval of 0.01 second is adequate.

Table 6. Seismic Analysis Matrix

Structure	Set A(1)	Set B(2)	Set C(3)	Eval	New Design or Modif (4)
Interior Concrete Structure	E	Y	Y	B	B+C
Steel Containment Vessel	E	Y	Y	B	B+C
Shield Building	E	Y	Y	B	B+C
Diesel Generator Building	E	Y	Y	B	B+C
Additional Diesel Generator Building	*	Y	Y	B+C	B+C
North Steam Valve Room	E	Y	Y	B	B+C
Auxiliary/Control Building	E	Y	Y	B	B+C
Refueling Water Storage Tank	E	Y	Y	B	B+C
Intake Pumping Station	E	Y	Y	B	B+C
Pipe Tunnels	**	Y	Y	B+C	B+C

E = existing analysis
* = original analysis criteria were established subsequent to SER. These criteria will be eliminated.
Y = yes, analysis is needed
** = Original spectra were not explicitly developed.

Notes:

1. Set A refers to original analysis.
2. Set B refers to SRP - compatible analysis using SSRS
3. Set C refers to reanalysis using original criteria and current modeling
4. B + C indicates envelop of B and C results.

Table 7. Seismic Criteria and Methodology for Systems and Components for Evaluation and New Design or Modification

Attributes	Criteria and Methodology
Damping for Sets B, C, and the envelop of B and C (See Table 8 for values)	Use damping values based on ° RG 1.61 ° N411 ° Test Results
Analysis techniques	Use SRP - Compatible approaches ° Equivalent Static ° Response Spectrum Analysis (RSA) ° T-H Analysis (THA) (1)
Accounting for Uncertainties	Peak broadening (RSA) Peak shifting (THA)
Spatial Combinations	2D Absolute sum except for piping 3D Square-root-of-sum-of-squares for piping

(1) In performing T-H analysis with single set of T-Hs, adequacy of energy content shall be demonstrated.

Table 8. Seismic Criteria for System and Component Damping for Evaluation and New Design or Modification

Item	Proposed For Evaluation and Modification or New Design		Justification Source For Proposed Values
	OBE	SSE	
Piping			
12" or Larger	2	3	RG 1.61
Less than 12"	1	2	RG 1.61
Optional (code Case)	N411	N411	RG 1.84
Cable Tray System	7	7	Test Results (1)
Conduit System	7	7	Test Results (1)
HVAC Systems			Nuclear Air Cleaning Handbook and Test Results (1)
Companion Angle	5	7	
Pocket Lock	7	7	
Welded Duct	2	5	
Equipment	2	3	RG 1.61

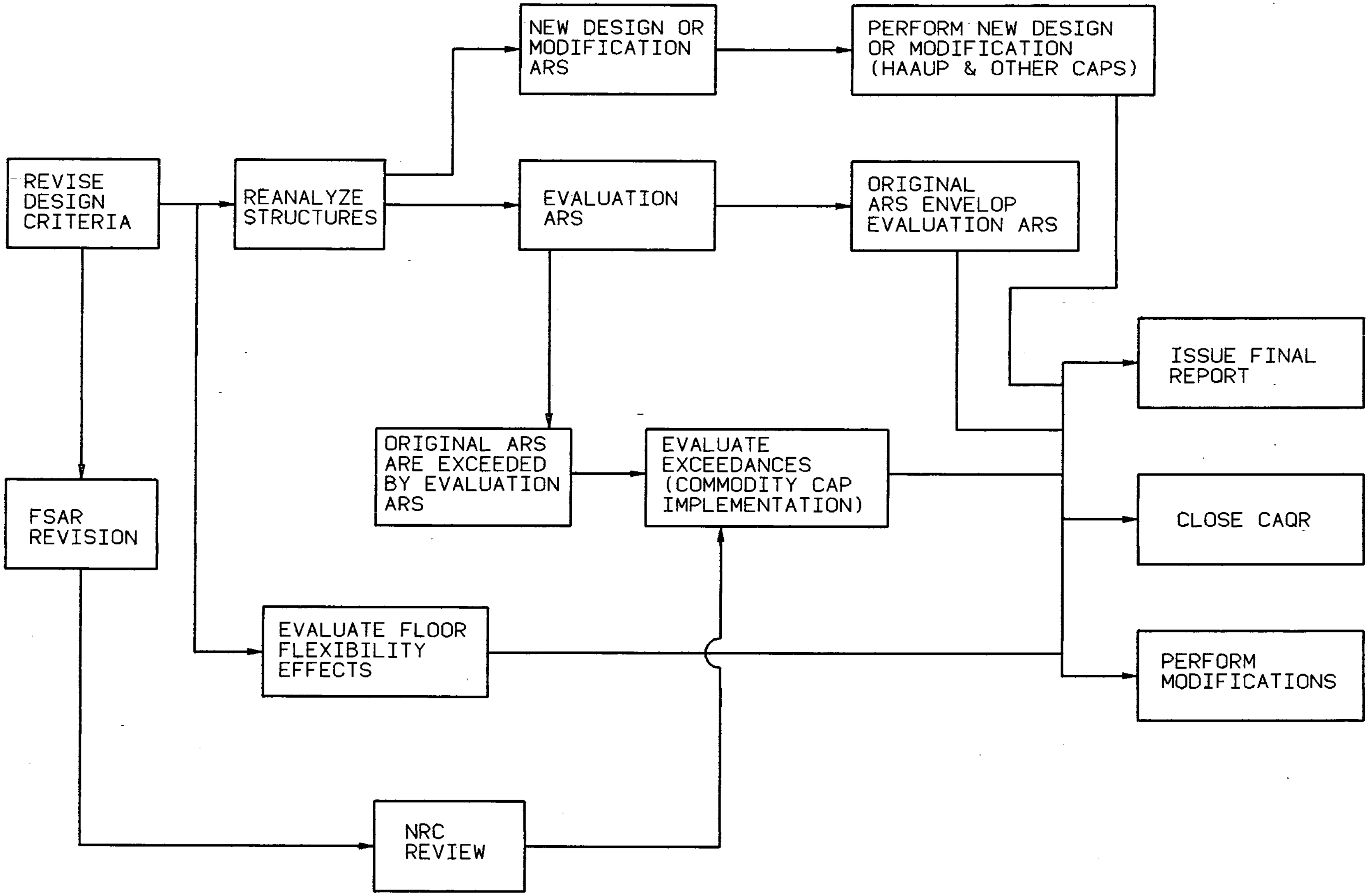
(1) Higher Damping may be used in specific applications if supported by test data and endorsed by NRC.

ATTACHMENT 1

LIST OF EMPLOYEE CONCERN AND CAQRs

Item	Document	Description
1	ECP-87-KX-009-01 (L77 870608 804)	Concern with integration time step used to perform the time-history analysis. The time step used may be too large to calculate high frequency response adequately.
2	CAQR WBF 870038R1 (B05 870706 300)	Concern with soil structure interaction (SSI) analysis for the design of the pile foundation for Condensate Demineralizer Waste Evaporator Building. The analysis may not reflect the maximum loading condition for the piles and the soil spring constants used in analysis may not be realistic.
3	CAQR WBF 870039R1 (B05 870729 306)	Concern with SSI analyses for the design of the pile foundation for the Additional Diesel Generator Building. The concern is similar to that of Condensate Demineralizer Waste Evaporator Building analysis.
4	CAQR WBP 870396R0 (T42 870528 975)	Concern regarding the soil modulus for crushed stone for Diesel Generator Building and Waste Packaging Area.

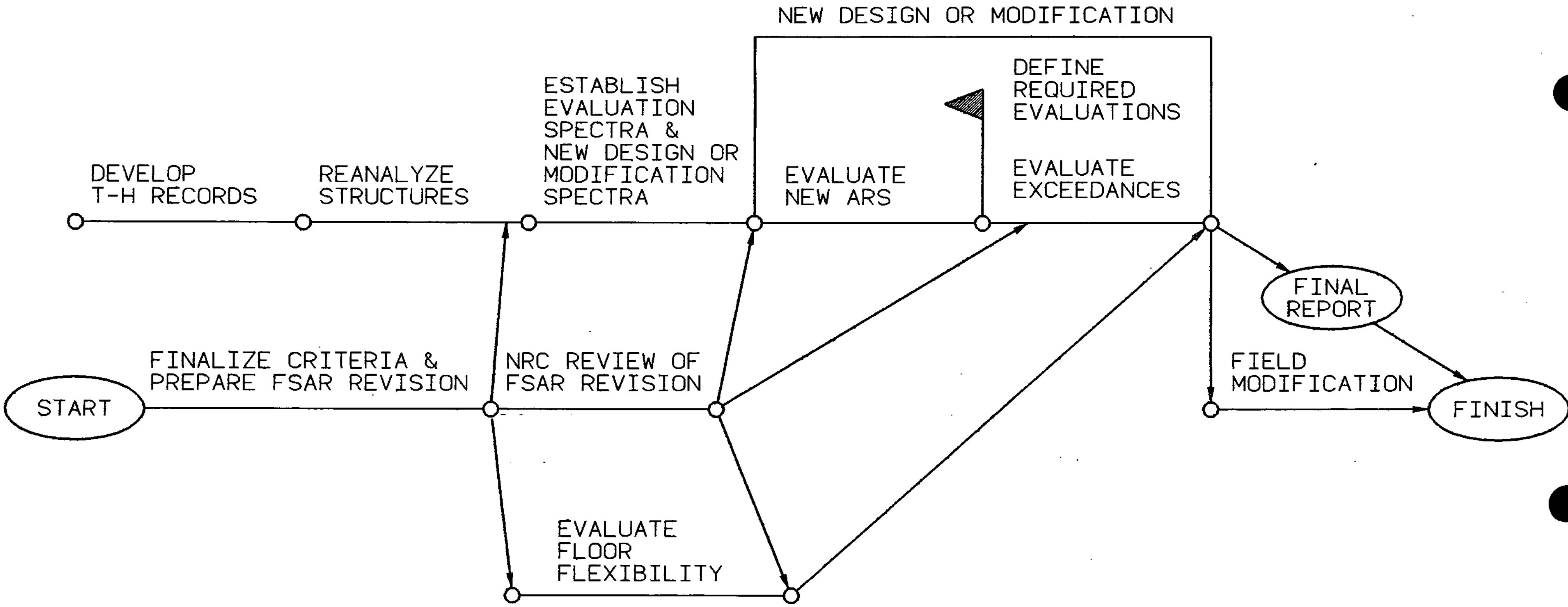
WATTS BAR NUCLEAR PLANT
SEISMIC ANALYSIS CAP FLOWCHART



ATTACHMENT 2

WBN MIS391 0,0,0 DHW

WATTS BAR NUCLEAR PLANT
SEISMIC ANALYSIS CAP FRAGNET



ATTACHMENT 3

WBN MIS392 0,0,0 JKA