Attachment A

Arkansas Natural Heritage Commission Correspondence

- Letter from Dr. Gary Tucker, FTN Associates, LTD., to Cindy Osborne, Arkansas Natural Heritage Commission, dated September 17, 2002
- Letter from Cindy Osborne, Arkansas Natural Heritage Commission to Gary Tucker, FTN Associates, LTD., dated October 4, 2002

ftn Associates Ltd.
water resources / environmental consultants

September 17, 2002

Ms. Cindy Osborne
Arkansas Natural Heritage Commission
1400 Tower Building
323 Center
Little Rock, AR 72201

RE: Request for Element Occurrence Information
Arkansas Nuclear One (Unit-2) located near Russellville, Pope County, AR
FTN No. 6045-062

Dear Ms. Osborne:

The purpose of this letter is to request element occurrence data, i.e., for federal and state listed species and other elements tracked by your agency, for the ANO facility and the existing ANO-2 500 kV transmission line corridor. The enclosed USGS topographic maps (Figure 1) shows the location of the facility and transmission corridor. As indicated, we are requesting element occurrence information within the facility boundary and width of the transmission line corridors only.

For your information, ANO-2 went online in 1980 by authorization of a license issued by Nuclear Regulatory Commission. Entergy is currently preparing a license renewal application which, if approved by the NRC, will extend the operating license from 2018 to 2038. Please note that the application addresses only a continuation of existing operations and does not involve refurbishment, major construction activities or other significant changes in the design or operation of the facility.

If you have questions or need additional information, please feel free to call me or Bob West at (501) 225-7779.

Kindest regards,
FTN ASSOCIATES, LTD.

Gary E. Tucker, PhD, PWS
Environmental Scientist

Enclosure

cc: Rick Buckley – Entergy
Alan Cox – Entergy
Garry Young – Entergy

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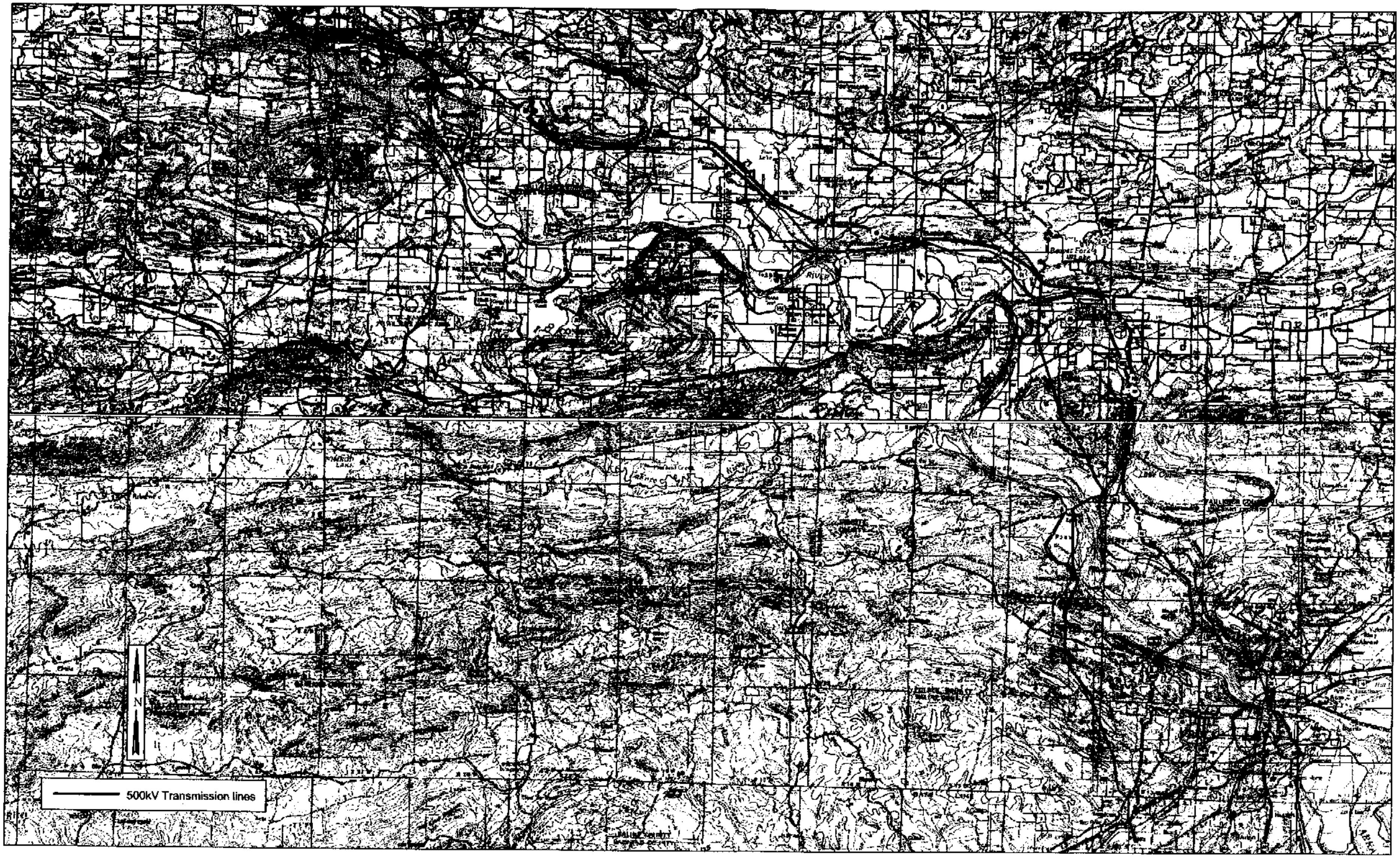

Figure 1. Approximate location of ANO-2 500 kV transmission line.

The Department of
Arkansas Heritage

Mike Huckabee, Governor
Cathie Mathews, Director

Arkansas Arts Council
▪
Arkansas Historic Preservation Program
▪
Historic Arkansas Museum
▪
Delta Cultural Center
▪
Old State House Museum

Arkansas Natural Heritage Commission

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Date: October 4, 2002
Subject: Elements of Special Concern
Arkansas Nuclear One (Unit 2)
500 kV transmission line Corridor
ANHC No.: P-CF..-02-080

Dr. Gary Tucker
FTN Associates Ltd.
3 Innwood Circle
Suite 220
Little Rock, AR 72211

Dear Dr. Tucker:

Staff members of the Arkansas Natural Heritage Commission have reviewed our files for records indicating the occurrence of rare plants and animals, outstanding natural communities, natural or scenic rivers, or other elements of special concern at the Arkansas Nuclear One site and along the existing 500 kV transmission line corridor. We find no records of sensitive resources at the Nuclear One site. Several features of interest have been identified along the transmission line corridor.

In 1999 this agency responded to a request from FTN Associates Ltd. for sensitive resources known to occur at the Nuclear One site and along most of the transmission line corridor. The following features of interest to this agency were identified in that search:

1. An occurrence of mock orange (*Phidelphus hirsutus*) on Crow Mountain in the general vicinity of the transmission line,
2. An occurrence of Ozark chinquapin (*Castanea pumila* var. *ozarkensis*) on Crow Mountain in the general vicinity of the transmission line,
3. Goose Pond Natural Area within the Ed Gordon/Point Remove Wildlife Management Area (transmission line traverses southwest corner),
4. Illinois Bayou (Registry of State Natural and Scenic Rivers, Arkansas Department of Environmental Quality Extraordinary Resource Water) transmission line crossing
5. Cadron Creek (Registry of State Natural and Scenic Rivers, Arkansas Department of Environmental Quality Extraordinary Resource Water) transmission line crossing.

Detailed information on these resources was provided to FTN in that correspondence. At your request, a new search has been conducted. This search included the Nuclear One Site, a portion of the powerline previously searched, and a small section of powerline corridor at the

6045-062 ANO

southern end of the project, not previously searched. Our new review revealed no additional features of special concern or new information.

Updated county element lists for Pope, Conway, Faulkner, and Pulaski Counties are enclosed for your reference. Represented on these lists are elements for which we have records in our database. A legend is enclosed to help you interpret the codes on these lists.

Please keep in mind that the project area may contain important natural features of which we are unaware. Staff members of the Arkansas Natural Heritage Commission have not conducted a field survey of the Nuclear One site or the transmission line corridor. Our review is based on data available to the program at the time of the request. It should not be regarded as a final statement on the elements or areas under consideration, nor should it be substituted for on-site surveys required for environmental assessments. Because our files are updated constantly, you may want to check with us again at a later time.

Thank you for consulting us. It has been a pleasure to work with you on this study.

Sincerely,

Cindy Osborne

Cindy Osborne
Data Manager

Enclosures: Legend
Pope, Conway, Faulkner, Pulaski County Element Lists
Invoice

LEGEND

STATUS CODES

FEDERAL STATUS CODES

C	=	Candidate species. The U.S. Fish and Wildlife Service has enough scientific information to warrant proposing these species for listing as endangered or threatened under the Endangered Species Act.
LE	=	Listed Endangered; the U.S. Fish and Wildlife Service has listed these species as endangered under the Endangered Species Act.
LT	=	Listed Threatened; the U.S. Fish and Wildlife Service has listed these species as threatened under the Endangered Species Act.
LELT	=	Listed Endangered and Threatened; the U.S. Fish and Wildlife Services has listed these species as endangered and threatened in different parts of the breeding range.
-PD	=	Proposed for Delisting; the U.S. Fish and Wildlife Service has proposed that this species be removed from the list of Endangered or Threatened Species.
PE	=	Proposed Endangered; the U.S. Fish and Wildlife Service has proposed these species for listing as endangered.
PT	=	Proposed Threatened; the U.S. Fish and Wildlife Service has proposed these species for listing as threatened.
T/SA E/SA	=	Threatened (or Endangered) because of similarity of appearance.

STATE STATUS CODES

INV	=	Inventory Element; The Arkansas Natural Heritage Commission is currently conducting active inventory work on these elements. Available data suggests these elements are of conservation concern. These elements may include outstanding examples of Natural Communities, colonial bird nesting sites, outstanding scenic and geologic features as well as plants and animals which, according to current information, may be rare, peripheral, or of an undetermined status in the state. The ANHC is gathering detailed location information on these elements.
MON	=	Monitored Species; The Arkansas Natural Heritage Commission is currently monitoring information on these species. These species do not have conservation concerns at present. They may be new species to the state, or species on which additional information is needed. The ANHC is gathering detailed location information on these elements.
WAT	=	Watch List Species; The Arkansas Natural Heritage Commission is not conducting active inventory work on these species, however, available information suggests they may be of conservation concern. The ANHC is gathering general information on status and trends of these elements. An "*" indicates the status of the species will be changed to "INV" if the species is verified as occurring in the state (this typically means the agency has received a verified breedign record for the species).
SE	=	State Endangered; The Arkansas Natural Heritage Commission applies this term to native plant taxa which are in danger of being extirpated from the state.
ST	=	State Threatened; The Arkansas Natural Heritage Commission applies this term to native plant taxa which are believed likely to become endangered in Arkansas in the foreseeable future, based on current inventory information.

DEFINITION OF RANKS

Global Ranks

G1	=	Critically imperiled globally because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2	=	Imperiled globally because of rarity (6-20 occurrences or few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

G3	=	Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single western state, a physiographic region in the East) or because of other factors making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 - 100.
G4	=	Apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery.
G5	=	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GH	=	Of historical occurrence throughout its range, i.e., formerly part of the established biota, with the expectation that it may be rediscovered (e.g., Bachman's Warbler).
GU	=	Possibly in peril range-wide but status uncertain; more information needed.
GX	=	Believed to be extinct throughout range (e.g., Passenger Pigeon) with virtually no likelihood that it will be rediscovered.
T-RANKS	=	T subranks are given to global ranks when a subspecies, variety, or race is considered at the state level. The subrank is made up of a "T" plus a number or letter (1, 2, 3, 4, 5, H, U, X) with the same ranking rules as a full species.

State Ranks

S1	=	Extremely rare. Typically 5 or fewer estimated occurrences in the state, or only a few remaining individuals, may be especially vulnerable to extirpation.
S2	=	Very rare. Typically between 5 and 20 estimated occurrences or with many individuals in fewer occurrences, often susceptible to becoming extirpated.
S3	=	Rare to uncommon. Typically between 20 and 100 estimated occurrences, may have fewer occurrences but with large number of individuals in some populations, may be susceptible to large-scale disturbances.
S4	=	Common, apparently secure under present conditions. Typically 100 or more estimated occurrences, but may be fewer with many large populations, may be restricted to only a portion of the state, usually not susceptible to immediate threats.
S5	=	Demonstrably widespread, common, and secure in the state and essentially inerradicable under present conditions.
SA	=	Accidental.
SH	=	Historically known from the state, but not verified for an extended period, usually 15 years.
SU	=	Possibly in peril in the state, but status uncertain, more information is needed.
SX	=	Apparently extirpated from state.
SZ	=	Zero occurrences. Not of practical conservation concern in the state because there are no definable occurrences, although the taxa is native and appears regularly in the state.

General Ranking Notes

Q	=	A "Q" in the global rank indicates the element's taxonomic classification as a species is a matter of conjecture among scientists.
RANGES	=	Ranges are used temporarily until a final rank decision can be made.
?	=	A question mark is used temporarily when there is some indecision regarding the rank assignment or when an element has not been ranked.
B	=	Breeding status
N	=	Non-breeding status

11/5/2001

Arkansas Natural Heritage Commission
Department of Arkansas Heritage
Inventory Research Program
Conway County

Scientific Name	Common Name	Fed. Status	State Status	Global Rank	State Rank
Animals-Invertebrates					
Lirceus bicuspidatus	an isopod	-	INV	G3Q	S3
Speyeria diana	Diana	-	INV	G3	S2S3
Animals-Vertebrates					
Hyla avivoca	bird-voiced treefrog	-	INV	G5	S2
Puma concolor coryi	Florida panther	LE	INV	G5T1	SH
Spea bombifrons	plains spadefoot	-	INV	G5	S1
Sterna antillarum athalassos	interior least tern	LE	INV	G4T2Q	S2B
Thryomanes bewickii	Bewick's wren	-	INV	G5	S2B,S3N
Plants-Vascular					
Agalinis homalantha	San Antonio false-foxglove	-	INV	G5	S1
Amorpha ouachitensis	Ouachita leadplant	-	INV	G3Q	S3
Castanea pumila var ozarkensis	Ozark chinquapin	-	INV	G5T3	S3S4
Croptilon hookerianum var validum	scratch-daisy	-	INV	G5?T5	S2
Eriocaulon koernickianum	small-headed pipewort	-	SE	G2	S2
Eustoma russellianum	showy prairie-gentian	-	INV	G5	S2
Gentiana saponaria	soapwort gentian	-	INV	G5	S3
Heuchera parviflora var puberula	little-leaved alumroot	-	INV	G4T3T4	S3
Neviusia alabamensis	Alabama snow wreath	-	ST	G2	S1S2
Pilularia americana	American pillwort	-	INV	G5	S2
Platanthera flava	southern rein-orchid	-	ST	G4	S1S2
Ranunculus flabellaris	yellow water-crowfoot	-	INV	G5	S3
Saxifraga virginiensis	Virginia saxifrage	-	INV	G5	S3
Selaginella arenicola ssp riddellii	Riddell's spike moss	-	INV	G4T4	S3
Smilax tamnoides	bristly greenbrier	-	INV	G5	S2
Trichomanes petersii	dwarf filmy-fern	-	ST	G4G5	S2
Special Elements-Natural Communities					
Cypress swamp		-	INV	-	S3
Mesic oak-hickory forest		-	INV	-	S4
Sandstone glade/outcrop		-	INV	-	S4
Special Elements-Other					
Colonial nesting site, water birds		-	INV	-	-
Geological feature		-	INV	-	-

Arkansas Natural Heritage Commission
Department of Arkansas Heritage
Inventory Research Program
Faulkner County

Scientific Name	Common Name	Fed. Status	State Status	Global Rank	State Rank
Animals-Invertebrates					
Speyeria diana	Diana	-	INV	G3	S2S3
Animals-Vertebrates					
Deirochelys reticularia miaria	western chicken turtle	-	INV	G5T5	S3
Haliaeetus leucocephalus	bald eagle	LT-PD	INV	G4	S2B,S4N
Hyla avivoca	bird-voiced treefrog	-	INV	G5	S2
Pandion haliaetus	osprey	-	INV	G5	S1B,S4N
Pseudacris streckeri streckeri	Strecker's chorus frog	-	INV	G5T5	S2
Regina septemvittata	queen snake	-	INV	G5	S2
Sterna antillarum athalassos	interior least tern	LE	INV	G4T2Q	S2B
Tadarida brasiliensis	Brazilian free-tailed bat	-	INV	G5	S3
Thryomanes bewickii	Bewick's wren	-	INV	G5	S2B,S3N
Plants-Vascular					
Allium stellatum	glade onion	-	INV	G5	S3
Antennaria neglecta	field pussytoes	-	INV	G5	S1
Carex crawei	Crawe's sedge	-	INV	G5	S3
Castanea pumila var ozarkensis	Ozark chinquapin	-	INV	G5T3	S3S4
Claytonia caroliniana	Carolina spring-beauty	-	INV	G5	S2S3
Draba aprica	open-ground whitlow-grass	-	ST	G3	S2
Heuchera villosa var arkansana	Arkansas alumroot	-	INV	G5T3Q	S3
Marsilea vestita	hairy water-fern	-	INV	G5	S3
Minuartia drummondii	Drummond's sandwort	-	INV	G5	S2S3
Neviusia alabamensis	Alabama snow wreath	-	ST	G2	S1S2
Paronychia virginica var scoparia	a paronychia	-	INV	G4T4Q	S2
Phacelia gilioides	brand phacelia	-	INV	G5	S2S3
Philadelphus hirsutus	a mock orange	-	INV	G5	S2S3
Pilularia americana	American pillwort	-	INV	G5	S2
Platanthera peramoena	purple fringeless orchid	-	ST	G5	S2
Podostemum ceratophyllum	threadfoot	-	INV	G5	S3
Potentilla arguta	tall cinquefoil	-	ST	G5	S1S2
Quercus coccinea	scarlet oak	-	INV	G5	S2S3
Rhynchospora cephalantha	capitate beak rush	-	INV	G5	SH
Rudbeckia maxima	a blackeyed susan	-	INV	G4?	S3
Saxifraga virginiensis	Virginia saxifrage	-	INV	G5	S3
Scleria pauciflora	fewflower nutrush	-	INV	G5	S3
Smilax tamnoides	bristly greenbrier	-	INV	G5	S2
Spiranthes odorata	sweetscent ladies'-tresses	-	INV	G5	S1
Streptanthus obtusifolius	a twistflower	-	INV	G3	S3
Valerianella ozarkana	a corn-salad	-	INV	G3	S3
Special Elements-Natural Communities					
Juniper-hardwood woodland		-	INV	-	S4
Upland headwater stream-Arkansas Valley		-	INV	-	-
Special Elements-Other					
Colonial nesting site, water birds		-	INV	-	-

11/6/2001

Arkansas Natural Heritage Commission
Department of Arkansas Heritage
Inventory Research Program
Pope County

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Animals-Invertebrates					
Anodonta suborbiculata	flat floater	-	INV	G5	S1?
Cambarus causeyi	a crayfish	-	INV	G1	S1
Lirceus bicuspidatus	an isopod	-	INV	G3Q	S3
Scaphinotus inflectus	a ground beetle	-	INV	G?	S?
Animals-Vertebrates					
Corynorhinus rafinesquii	Rafinesque's big-eared bat	-	INV	G3G4	S2
Hybognathus placitus	plains minnow	-	INV	G4	SX
Hyla avivoca	bird-voiced treefrog	-	INV	G5	S2
Myotis grisescens	gray myotis	LE	INV	G3	S2
Notropis girardi	Arkansas River shiner	LT	INV	G2	SX
Percina nasuta	longnose darter	-	INV	G3	S2
Pseudacris streckeri streckeri	Strecker's chorus frog	-	INV	G5T5	S2
Rana areolata circulosa	northern crawfish frog	-	INV	G4T4	S3
Regina septemvittata	queen snake	-	INV	G5	S2
Spea bombifrons	plains spadefoot	-	INV	G5	S1
Sterna antillarum athalassos	interior least tern	LE	INV	G4T2Q	S2B
Plants-Vascular					
Carex careyana	Carey's sedge	-	INV	G5	S2
Carex communis	fibrous-root sedge	-	INV	G5	S2S3
Castanea pumila var ozarkensis	Ozark chinquapin	-	INV	G5T3	S3S4
Caulophyllum thalictroides	blue cohosh	-	INV	G4G5	S2
Delphinium newtonianum	Moore's larkspur	-	INV	G3	S3
Draba aprica	open-ground whitlow-grass	-	ST	G3	S2
Eriocaulon komickianum	small-headed pipewort	-	SE	G2	S2
Euphorbia hexagona	six-angle spurge	-	INV	G5	S2
Heuchera villosa var arkansana	Arkansas alumroot	-	INV	G5T3Q	S3
Hydrocotyle americana	American water-pennywort	-	INV	G5	SH
Malus coronaria	sweet crab-apple	-	INV	G5	S2S3
Mimulus floribundus	floriferous monkeyflower	-	INV	G5	S2S3
Neviusia alabamensis	Alabama snow wreath	-	ST	G2	S1S2
Osmunda claytoniana	interrupted fern	-	ST	G5	S1
Philadelphus hirsutus	a mock orange	-	INV	G5	S2S3
Podostemum ceratophyllum	threadfoot	-	INV	G5	S3
Sanicula smallii	Small's sanicle	-	INV	G5	S3
Selaginella arenicola ssp riddellii	Riddell's spike moss	-	INV	G4T4	S3
Silene ovata	ovate-leaf catchfly	-	ST	G2G3	S3
Tradescantia ozarkana	Ozark spiderwort	-	INV	G3	S3
Tradescantia subaspera	a spiderwort	-	INV	G5	S1S3
Trichomanes petersii	dwarf filmy-fern	-	ST	G4G5	S2
Special Elements-Natural Communities					
Mesic oak-hickory forest		-	INV	-	S4
Overcup oak forest		-	INV	-	S2
River front forest		-	INV	-	S3
Sandstone glade/outcrop		-	INV	-	S4
Tallgrass prairie		-	INV	-	S2
Upland stream-Ozark Mountains		-	INV	-	-

Pope County (cont.)

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Special Elements-Other					
Colonial nesting site, water birds		-	INV	-	-
Geological feature		-	INV	-	-

Arkansas Natural Heritage Commission
Department of Arkansas Heritage
Inventory Research Program
Pulaski County

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Animals-Invertebrates					
Anodonta suborbiculata	flat floater	-	INV	G5	S1?
Arianops copelandi	Copeland's mold beetle	-	INV	G?	S1
Lirceus bicuspidatus	an isopod	-	INV	G3Q	S3
Speyeria diana	Diana	-	INV	G3	S2S3
Animals-Vertebrates					
Aimophila ruficeps	rufous-crowned sparrow	-	INV	G5	S1
Ambystoma annulatum	ringed salamander	-	INV	G4	S4
Cemophora coccinea copei	northern scarlet snake	-	INV	G5T5	S5
Gallinula chloropus	common moorhen	-	INV	G5	S1B,S2N
Haliaeetus leucocephalus	bald eagle	LT-PD	INV	G4	S2B,S4N
Hyla avivoca	bird-voiced treefrog	-	INV	G5	S2
Limnothlypis swainsonii	Swainson's warbler	-	INV	G4	S3B
Nerodia cyclopion	green water snake	-	INV	G5	S4
Picoides borealis	red-cockaded woodpecker	LE	INV	G3	S2
Polyodon spathula	paddlefish	-	INV	G4	S2?
Porphyrula martinica	purple gallinule	-	INV	G5	S1B
Pseudacris streckeri streckeri	Strecker's chorus frog	-	INV	G5T5	S2
Pseudacris triseriata triseriata	western chorus frog	-	INV	G5T5	S3
Rallus elegans	king rail	-	INV	G4G5	S1B,S3N
Rana sylvatica	wood frog	-	INV	G5	S4
Regina rigida sinicola	gulf crayfish snake	-	INV	G5T5	S3
Sterna antillarum athalassos	interior least tern	LE	INV	G4T2Q	S2B
Tadarida brasiliensis	Brazilian free-tailed bat	-	INV	G5	S3
Plants-Vascular					
Carex atlantica ssp capillacea	a sedge	-	INV	G5T5?	S2
Carex bromoides	a sedge	-	INV	G5	S2
Carex hyalina	tissue sedge	-	INV	G4	S3
Carex stricta	upright sedge	-	INV	G5	S1S3
Carex verrucosa	a sedge	-	INV	G3G4	SH
Castanea pumila var ozarkensis	Ozark chinquapin	-	INV	G5T3	S3S4
Chamaelirium luteum	devil's-bit	-	INV	G5	S3
Cynoctonum mitreola	lax hornpod	-	INV	G5	S3
Cypripedium kentuckiense	southern lady's-slipper	-	INV	G3	S3
Eriocaulon kornickianum	small-headed pipewort	-	SE	G2	S2
Eustoma russellianum	showy prairie-gentian	-	INV	G5	S2
Gentiana saponaria	soapwort gentian	-	INV	G5	S3
Hieracium scabrum	rough hawkweed	-	INV	G5	S2
Lithospermum incisum	narrow-leaved puccoon	-	INV	G5	S2S3
Marshallia caespitosa var signata	Barbara's buttons	-	INV	G4T4	S1
Marsilea vestita	hairy water-fern	-	INV	G5	S3
Nyssa biflora	swamp black gum	-	INV	G5	S1S3
Platanthera cristata	yellow-crested orchid	-	INV	G5	S1S2
Platanthera flava	southern rein-orchid	-	ST	G4	S1S2
Platanthera peramoena	purple fringeless orchid	-	ST	G5	S2
Pycnanthemum virginianum	Virginia mountain-mint	-	INV	G5	S1S2
Ranunculus flabellaris	yellow water-crowfoot	-	INV	G5	S3

Pulaski County (cont.)

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Ranunculus longirostris	white water-crowfoot	-	INV	G5	S2S3
Rhynchospora colorata	white-top sedge	-	SE	G5	S1
Sabatia campanulata	slender marsh pink	-	SE	G5	S1
Saxifraga virginiensis	Virginia saxifrage	-	INV	G5	S3
Sedum ternatum	wood stonecrop	-	INV	G5	S3
Spiraea tomentosa	hardhack	-	INV	G5	S2
Stenanthium gramineum	eastern featherbells	-	INV	G4G5	S3
Streptanthus obtusifolius	a twistflower	-	INV	G3	S3
Thelypteris noveboracensis	New York fern	-	INV	G5	S3
Tradescantia longipes	a spiderwort	-	INV	G4	S2
Trifolium stoloniferum	running buffalo clover	LE	INV	G3	SH
Trillium pusillum var ozarkanum	Ozark least trillium	-	INV	G3T3	S3
Valerianella ozarkana	a corn-salad	-	INV	G3	S3
Special Elements-Natural Communities					
Cattail marsh		-	INV	-	S1S2
Nepheline syenite (igneous) glade/outcrop		-	INV	-	S1
Special Elements-Other					
Colonial nesting site, swallows & swifts		-	INV	-	-
Colonial nesting site, water birds		-	INV	-	-
Geological feature		-	INV	-	-

Attachment B

U.S. Fish and Wildlife Service Correspondence

- Letter from Dr. Gary Tucker, FTN Associates, LTD., to Margaret Harney, U.S. Fish and Wildlife Service, dated September 17, 2002
- Letter from Allan J. Mueller, U.S. Fish and Wildlife Service, to Dr. Gary Tucker, FTN Associates, LTD., dated December 20, 2002

ftn Associates Ltd.
water resources / environmental consultants

September 17, 2002

Ms. Margaret Harney
US Fish and Wildlife Service
1500 Museum Road
Suite 105
Conway, AR 73032

RE: Request for Information Regarding Federally Listed Threatened and Endangered Species
Arkansas Nuclear One (Unit-2) License Renewal Project, Russellville, Pope County, AR
FTN No. 6045-062

Dear Ms. Harney:

The purpose of this letter is to request available information regarding federally listed threatened and endangered (T&E) species near Entergy's Arkansas Nuclear One, Unit-2 (ANO-2) facility and its associated 500 kV transmission line. You may recall that we requested similar information in 1999 during the preparation of the ANO-1 license renewal application.

We are specifically interested in identifying any new information regarding T&E species of concern near the ANO-2 facility and within the transmission line right-of-way, which extends approximately 90 miles from the facility to Mablevale. Enclosed is a topographic map (Figure 1) that shows the location of the facility and the transmission line.

Construction of ANO-2 was completed in 1980. The operating license for the plant is scheduled to expire in 2018. Entergy is currently preparing a license renewal application which will be submitted to the Nuclear Regulatory Commission in 2003. The application will request the ANO-2 license be extended from 2018 to 2038.

Please note that the application addresses only a continuation of existing operations and does not involve refurbishment, major construction activities, or other significant changes related to the design and operation of the facility.

3 Innwood Circle • Suite 220 • Little Rock, AR 72211
(501) 225-7779 • Fax (501) 225-6738
2949 Point Circle • Suite 1 • Fayetteville, AR 72704
(501) 571-3334 • Fax (501) 571-3338
Web Site: www.ftn-assoc.com
E-mail: ftn@ftn-assoc.com

If you have questions or need additional information, please feel free to call Bob West or me at (501) 225-7779.

Kindest regards,
FTN ASSOCIATES, LTD.

Gary E. Tucker, PhD, PWS
Environmental Scientist

Enclosure

CC: Rick Buckley – Entergy
Alan Cox – Entergy
Garry Young – Entergy

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
1500 Museum Road, Suite 105
Conway, Arkansas 72032
Tel.: 501/513-4470 Fax: 501/513-4480

IN REPLY REFER TO:

December 20, 2002

Dr. Gary E. Tucker
FTN Associates Ltd.
3 Innwood Circle, Suite 220
Little Rock, AR 72211

Dear Dr. Tucker:

The Fish and Wildlife Service (Service) has reviewed your September 17, 2002 request for endangered species information in connection with an application for the license extension of Entergy's Arkansas Nuclear One Unit-2 (ANO-2) and its associated 90 mile long, 500 kV transmission line. The requested twenty year license extension for ANO-2 is only for a continuation of present activities. Major construction activities, refurbishment, or other significant changes in facility operations or design are not included. Our comments are submitted in accordance with the Endangered Species Act (87 Stat. 884, as amended 16 U.S.C. 1531 et seq.) and the Fish and Wildlife Coordination Act (48 Stat., as amended 16 U.S.C. 661 et seq.).

The endangered interior population of the least tern (*Sterna antillarum athalassos*) is known to occur along portions of the Arkansas River, and the threatened Arkansas River shiner (*Notropis girardi*) has an historic occurrence in the river. No threatened or endangered species have been observed in the vicinity of ANO-2 or the transmission line. The Service anticipates the proposed license extension will have no adverse impact on federally listed species; however, we reserve the right to make further comments regarding possible impacts on non-listed species and/or their habitats as the application process continues.

We appreciate your interest in the preservation of endangered species. If you have any questions, please contact Elizabeth Stafford at (501) 513-4483.

Sincerely,

Allan J. Mueller

Allan J. Mueller
Field Supervisor

03-0073

2045-062 ANO-2 ER Support

Attachment C

Arkansas Game and Fish Commission Correspondence

- Letter from Dr. Gary Tucker, FTN Associates, LTD., to Craig Uyeda, Arkansas Game and Fish Commission, dated September 16, 2002
- Letter from Robert K. Leonard, Arkansas Game and Fish Commission, to Dr. Gary Tucker, FTN Associates, LTD., dated February 7, 2003

ftn Associates Ltd.
water resources / environmental consultants

September 16, 2002

Mr. Craig Uyeda, River Basins
Arkansas Game and Fish Commission
2 Natural Resources Drive
Little Rock, AR 72205

RE: Request for Information on Wildlife and Fisheries Species Issues
Arkansas Nuclear One (Unit-2) License Renewal Application
FTN No. 6045-062

Dear Mr. Uyeda:

The purpose of this letter is to request available information regarding wildlife and fisheries species issues of concern near Entergy's Arkansas Nuclear One, Unit-2 (ANO-2) facility and its associated 500 kV transmission line. The ANO-2 facility is located approximately 6 miles west of Russellville. You may recall that we requested similar information in 1999 during the preparation of the ANO-1 license renewal.

We are specifically interested in identifying any new information regarding wildlife species of concern near the ANO-2 facility and within the transmission line right-of-way, which extends approximately 90 miles from the facility to Mablevale. Enclosed is a topographic map (Figure 1) that shows the location of the facility and the transmission line.

Construction of ANO-2 was completed in 1980. The operating license for the plant is scheduled to expire in 2018. Entergy is currently developing a license renewal application which will be submitted to the Nuclear Regulatory Commission in 2003. The application will request the ANO-2 license be extended from 2018 to 2038. Please note that the application addresses only a continuation of existing operations and does not involve refurbishment, construction or other significant changes related to the design and operation of the facility.

If you have questions or need additional information, please feel free to call me or Bob West at (501) 225-7779.

Kindest regards,
FTN ASSOCIATES, LTD.

Gary E. Tucker, PhD, PWS
Environmental Scientist

Enclosure

CC: Rick Buckley – Entergy
Alan Cox – Entergy
Garry Young, PE – Entergy

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Web Site: www.ftn-assoc.com
E-mail: ftn@ftn-assoc.com

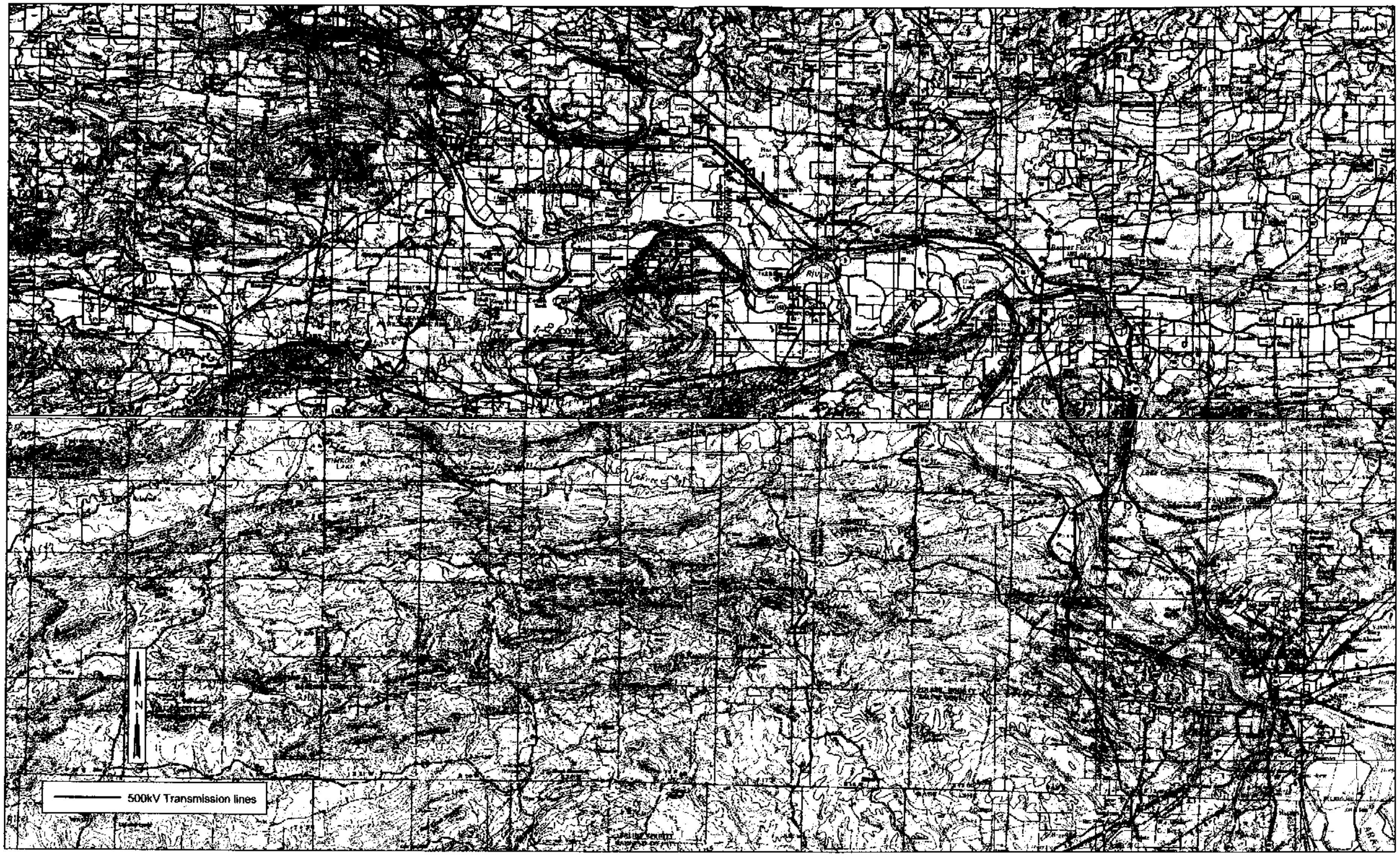

Figure 1. Approximate location of ANO-2 500 kV transmission line.

Arkansas Game & Fish Commission
2 Natural Resources Drive Little Rock, Arkansas 72205

Hugh C. Durham
Director

February 7, 2003

Gary E. Tucker, PhD, PWS
3 Innwood Circle
Suite 220
Little Rock, AR 72211

Dear Mr. Tucker:

Your letter dated September 16, 2002 regarding Information on wildlife and fisheries species issues in reference to a renewal application for Arkansas Nuclear One (Unit-2) has been referred to me for reply.

Biologists from our agency have conducted a preliminary review of the proposed renewal application for the above-mentioned subject and we anticipate insignificant adverse impacts to fish and wildlife resources.

We appreciate the opportunity to comment on this renewal application and look forward to working with you in the future.

Sincerely,

Robert K. Leonard

Robert K. Leonard Biologist
River Basin Division

Cc: Mike Gibson
Bob Limbird
USFWS

RECEIVED
FEB 10 2003
BY:

Attachment D

State Historic Preservation Office Correspondence

- Letter from Dr. Gary Tucker, FTN Associates, LTD., to George McCluskey, State Historic Preservation Office, dated October 4, 2002

- Letter from Ken Grunewald, State Historic Preservation Office, to Dr. Gary Tucker, FTN Associates, LTD., dated November 12, 2002

FTN Associates Ltd.
water resources / environmental consultants
3 Innwood Circle • Suite 220 • Little Rock, AR 72211 • (501) 225-7779 • Fax (501) 225-6738

October 4, 2002

Mr. George McCluskey
Senior Archeologist
State Historic Preservation Office
1500 Tower Building, 323 Center
Little Rock, AR 72201

RE: Cultural Resources Issues, Application for Extension of Nuclear Regulatory Commission License Period, Arkansas Nuclear One Facility, near Russellville, Pope County, Arkansas
FTN No. 6045-062

Dear Mr. McCluskey:

The purpose of this letter is to follow up on our October 2, 2002 meeting regarding re-licensing issues at Entergy's Arkansas Nuclear One (ANO) facility located near Russellville, Pope County, Arkansas. Entergy is currently preparing a license renewal application for ANO Unit-2. This application will be submitted to the Nuclear Regulatory Commission to extend the Unit-2 operating license an additional twenty years. As you may recall, a similar license renewal application for ANO Unit-1 was submitted to the NRC in 1999.

We are requesting from your office available information regarding potential cultural resources on the ANO site and its 500 kV transmission line that extends from the site to Mablevale. Attached are two maps that show the location of ANO (Figure 1) and its transmission line (Figure 2). During the preparation of the ANO Unit 1 License Renewal Application in 1999, we made a similar request for cultural resource information from your office. Specifically, we are seeking any new information that was not previously provided by your office in your letter dated June 18, 1999.

As we discussed during our October 2nd meeting, extending the operating license for ANO Unit-2 will not include any refurbishment, construction or modification activities at the site or within the transmission line right-of-way. Entergy plans to continue operating ANO Unit-2 and managing the transmission line as they have since construction was completed in the 1970's.

As part of ANO's operational practices, potential cultural resources within the undeveloped areas of the 1164 acre ANO site are protected by an Entergy administrative procedure. This procedure requires the ANO staff to perform an archeological survey prior to conducting any ground-disturbing activities within any undisturbed areas of the site and contact your office as applicable, dependent on findings from the evaluation.

Please provide us with a written response as to whether any additional cultural resource information exists. Again, we want to emphasize the fact that the current application to NRC involves no new construction or replacement of existing transmission lines. Instead, the application is concerned only with a request for an extension of the operating license for the ANO Unit-2 facility.

If you have questions or need additional information, please feel free to call me or Bob West at (501) 225-7779.

Kindest regards,
FTN ASSOCIATES, LTD.

FOR GET

Gary E. Tucker, PhD, PWS
Environmental Scientist

GET/sec

Enclosure

cc: Rick Buckley – Entergy

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The Department of
Arkansas
Heritage

Mike Huckabee, Governor
Cathie Matthews, Director

Arkansas Arts Council
▪
Arkansas Natural Heritage Commission
▪
Historic Arkansas Museum
▪
Delta Cultural Center
▪
Old State House Museum

Arkansas Historic Preservation Program

1500 Tower Building
323 Center Street
Little Rock, AR 72201
(501)324-9880
fax: (501)324-9184
tdd: (501)324-9811
e-mail:
info@arkansaspreservation.org
website:
www.arkansaspreservation.org

November 12, 2002

Dr. Gary E. Tucker
Environmental Scientist
FTN Associates, Ltd.
3 Innwood Circle, Suite 220
Little Rock, Arkansas 72211

RE: Multi County – General
Section 106 Review – NRC
Proposed Nuclear One Facility License
Period Extension
AHPP Tracking Number 47149

Dear Dr. Tucker:

My staff has reviewed the information submitted on the proposed referenced undertaking. We have determined that 19 recorded archeological sites are located in or adjacent to the existing transmission lines. Should Entergy Inc. propose any new construction, these historic properties should be evaluated for their eligibility for inclusion in the National Register of Historic Places. Eligible sites that cannot be avoided should be mitigated by archeological data recovery.

Thank you for interest and concern for the cultural heritage of Arkansas. If you have any questions, please contact George McCluskey of my staff at (501) 324-9880.

Sincerely,

Ken Grunewald
Deputy State Historic Preservation Officer

cc: Nuclear Regulatory Commission
Arkansas Archeological Survey

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6045-062 ANO-2 ER Support

Attachment E

Severe Accident Mitigation Alternatives Analysis

Attachment E contains the following sections:

- E.1 – Melcor Accident Consequences Code System Modeling
- E.2 – Evaluation of SAMA Candidates

E.1 MELCOR ACCIDENT CONSEQUENCES CODE SYSTEM MODELING

E.1.1 Introduction

The following sections describe the assumptions made and the results of modeling performed to assess the risks and consequences of severe accidents at ANO-2.

The severe accident consequence analysis was carried out with the Melcor Accident Consequence Code System (Reference E.1-1). MACCS2 simulates the impact of severe accidents at nuclear power plants on the surrounding environment. The principal phenomena considered in MACCS2 are atmospheric transport, mitigating actions based on dose projection, dose accumulation by a number of pathways including food and water ingestion, early and latent health effects, and economic costs.

E.1.2 Input

The input data required by MACCS2 are outlined below.

E.1.2.1 Core Inventory

The core inventory in Table E.1-1 is for ANO-2 at a power level of 3026 megawatts-thermal (Reference E.1-11). These values were obtained by adjusting the end-of-cycle values for a 3,412 megawatts-thermal pressurized water reactor by a linear scaling factor of 0.887 (Reference E.1-1).

E.1.2.2 Source Terms

The source term input data to MACCS2 were the severe accident source terms presented in the probabilistic risk assessment in the ANO-2 IPE (Reference E.1-2). This document defines the releases in terms of release modes and demonstrates the method of calculating releases. There are 51 release modes: 20 with early containment failure, 25 with late containment failure, and 6 with containment bypass as the failure mode. Table E.1-2 lists the input release fractions for each MACCS2 nuclide group together with the source category frequencies calculated in the probabilistic risk assessment. For all modes the Ruthenium, Lanthanum, Cerium, and Barium fractions of the usual MACCS2 species were set to zero, as they were not reported in the IPE submittal. Assignment of the radionuclides in Table E.1-1 to these nuclide groups was the same as that of the standard MACCS2 input. Other related source term data, such as release durations and energies, were evaluated by comparison with similar releases reported in the NUREG-1150 studies for the Surry plant (Reference E.1-3).

The amount of each radionuclide released to the atmosphere for each accident sequence or release category was obtained by multiplying the core inventory at the time of the hypothetical accident (Table E.1-1) by the release fraction (Table E.1-2) assigned to each of the nuclide groups.

The off-site consequences were summed for the release modes weighted by the annual frequency to obtain the total annual accident risk for the baseline and for each of the SAMA candidates evaluated. (This summation calculation was performed outside of the MACCS2 code as part of the SAMA cost benefit analyses.)

E.1.2.3 Meteorological Data

The MACCS2 input included a full year (1996) of consecutive hourly values of wind speed, wind direction and stability class recorded at the site meteorological tower. Since the site did not record precipitation data for 1996, precipitation data was obtained for the nearest available recording site from the National Climatic Data Center of the National Oceanic and Atmospheric Administration of the U.S. Dept. of Commerce. This was the hourly precipitation recorded for 1996 at Clarksville 6 NE COOP STATION 03157, located at 35º 32' N, 93º 24' W (about 20 miles northwest of the ANO-2 site) (Reference E.1-4). The seasonal mixing heights for this area of Arkansas were taken from maps of mixing heights for the United States.

This weather data is representative and typical for the following reasons:

(a) The population density is relatively low near the plant. This, together with the weather sampling scheme used by MACCS2, tends to diminish the importance of year-to-year meteorological variations, and

(b) The SAMA analysis is concerned with differences, subtracting the SAMA effect from the baseline effect. Because of this differential approach, the effect of year-to-year weather variations on differential benefits is of second order importance, and does not significantly affect the results.

MACCS2 calculations examine a representative subset of the 8,760 hourly observations contained in one year's data set (typically about 150 sequences). The representative subset is selected by sampling the weather sequences after sorting them into weather bins defined by wind speed, atmospheric stability, and rain conditions at various distances from the site.

E.1.2.4 Population Distribution

The predicted population around the site for the year 2040 was distributed by location in a grid consisting of sixteen directional sectors, the first of which is centered on due north, the second on 22.5 degrees east of north, and so on. A summary of the population distribution is shown in Table E.1-3. The direction sectors were divided into 15 radial intervals extending out to 50 miles. The habitable land fraction for each grid element was calculated from land fraction data within a 50-mile radius of the plant.

The basis for the extrapolated population data is the 2000 census (Reference E.1-10) and the estimated 1998 transient population. The census data was obtained from the University of Arkansas/Little Rock Institute for Economic Advancement (the official repository of the Arkansas census data). The data was processed by first determining if the center (centroid) of a census block occurred within a grid sub-sector. If so, the population associated with that census block was assigned to that particular sub-sector. Since the centroid for one of the census blocks occurs with 0.65 miles of the plant, this standard practice makes it appear that 28 people reside with the exclusion area boundary. Actually, no one resides with the exclusion area boundary, and this is just an artifact of the population distribution process, and is considered conservative.

Before extrapolation to 2040, the 2000 population was adjusted to account for transient population. The transient population in the emergency planning zone (exclusion boundary of 0.65 miles to 10 miles) was estimated and added to the resident population. The area is a popular recreational zone and it was considered appropriate to add these individuals for dose estimation purposes (even though it results in an overestimation of the economic costs for non-farm property in this area). A similar approach was used for the ANO-1 SAMA (Reference E.1-9). For the ANO-1 analysis, the number of cars into each recreational area was taken from the Site Emergency Plan. From this source, the number of individuals in each sub-sector was estimated for 1980. For the ANO-2 analysis, the ANO-1 estimates were extrapolated to 2000 by using the ratio of Arkansas population in 2000 to Arkansas population in 1980 as a scale factor.

The 2000 census data (Reference E.1-10) and the 1990 census data (Reference E.1-5) were then used to project the future rosette section populations for the year 2040. A 50-mile radius growth factor was calculated by dividing the 50-mile radius population in 2000 by the 1990 population. This resulted in a growth factor of 27.34% per decade. The section population projection for 2040 was then estimated by extrapolating the 2000 section population according to this growth factor.

Using the 2040 projected population yields conservative results, since a severe accident and radiological release can only occur between now and the end of the period of extended operation (2038). The population in 2038 is likely to be less than that projected for 2040. Since economic impact is a function of population, the actual economic impact would be less than the estimated economic impact.

Since the population projections include transient population estimates in the 10-mile zone around the plant, the data is slightly larger in this zone than may be shown elsewhere in tables of population projections for the region.

E.1.2.5 Emergency Response

The evacuation modeling employed for the severe accident mitigation alternatives analyses was based on the site-specific evacuation plan (Reference E.1-7). The plan addresses evacuation of the population within the plume exposure emergency planning zone, a 10-mile radius centered on the plant site.

The emergency evacuation model was modeled as a single radial evacuation zone extending out 10 miles from the plant. In the plan, it is stated that 15% of the people will start moving 30 minutes after the alarm rings, 80% of people will start moving 90 minutes after the alarm rings, and 5% of the people will start moving 120 minutes after the alarm rings. The clear times for each of the four emergency planning zones were estimated by using weighted averages of the plan clear times for four different time periods, weekday, night, weekend, and adverse weekday. The average evacuation speed for the emergency zone was then estimated using the population-weighted average of the evacuation speed of each planning zone.

Because of the recreational nature of the area immediately surrounding the plant, the population in the emergency zone was augmented by adding the transient population to the census-based resident population. An average evacuation start time delay of 4950 seconds and an average radial evacuation speed of 1.2 m/s were estimated in the above manner. Due to the uncertainty of the population proportionality assumption, the value of 1.0 m/s (used in the ANO-1 SAMA analysis, Reference E.1-9) was used for the evacuation speed. A sensitivity analysis using the 1.2 m/s evacuation speed showed a drop of almost 9% in the population dose, demonstrating that the base case parameter generates conservative results.

For this analysis it was conservatively assumed that people beyond 10 miles would continue their normal activities unless the following predicted radiation dose levels are exceeded. At locations for which 50 rem whole body effective dose equivalent in one week is predicted, it was assumed that relocation would take place after half a day. If 25 rem whole body dose equivalent in one week is predicted, relocation of individuals in those sectors was assumed to take place after one day.

A sensitivity analysis was performed in which it was assumed that only 90% of the people within the emergency planning zone participated in the evacuation. The remaining 10% were assumed to be unable or unwilling to evacuate and were assumed to go about their normal activities. The results were not significantly different from the complete evacuation case. While the population doses increased and the evacuation costs decreased, the overall population exposure and accident mitigation costs are governed mainly by the long term effects over the whole 50-mile zone, and so the net changes were small.

Another sensitivity analysis was performed to assess the importance of the warning and release delay times. Two hours were subtracted from the base case alarm and delay times, while the late release start time was decreased from 150,000 seconds to 86,400 seconds to effect a comparable change. The results show that the duration has a small impact on the overall population dose since evacuees spend more time in the last phase of evacuation when there are more mechanisms for sheltering. The results demonstrate that the base case parameters generate conservative results.

The long-term phase was assumed to begin after one week and extend for five years. Long-term relocation was assumed to be triggered by a 4 rem whole body effective dose equivalent. Long-term protective measures were assumed to be based on generic protective action guideline levels for actions such as decontamination, temporary relocation, contaminated crops, and milk condemnation, and farmland production prohibition.

E.1.2.6 Economic Data

Land use statistics including farmland values, farm product values, dairy production, and growing season information were provided on a countywide basis within 50 miles.

The values used for these parameters were the same as those used for the ANO-1 analysis (Reference E.1-9). This data was taken from the computer program SECPOP90 (Reference E.1-5), which contains a database extracted from Bureau of the Census PL 94-171 (block level census) CD-ROMS (Reference E.1-6), the 1992 Census of Agriculture CD ROM Series 1B, the

1994 U.S. Census County and City Data Book CD-ROM, the 1993 and 1994 Statistical Abstract of the United States, and other minor sources. The reference contains details on how the database was created and checked. The regional economic values were updated to 2002 using the consumer price indices for 1997 and 2002 (Reference E.1-8).

Economic consequences were estimated by summing the following costs:

- Costs of evacuation,
- Costs for temporary relocation (food, lodging, lost income),
- Costs of decontaminating land and buildings,
- Lost return-on-investments from properties that are temporarily interdicted to allow contamination to be decreased by decay of nuclides,
- Costs of repairing temporarily interdicted property,
- Value of crops destroyed or not grown because they were contaminated by direct deposition or would be contaminated by root uptake, and
- Value of farmland and of individual, public, and non-farm commercial property that is condemned.

Table E.1-4 lists the values of the economic parameters used in MACCS2.

Costs associated with damage to the reactor, the purchase of replacement power, medical care, life-shortening, and litigation are not estimated by MACCS2.

E.1.3 Results

Using the preceding input data, MACCS2 was used to estimate the following:

- The downwind transport, dispersion, and deposition of the radioactive materials released to the atmosphere from the failed reactor containment.
- The short-term and long-term radiation doses received by exposed populations via direct (cloud shine, plume inhalation, ground shine, and re-suspension inhalation) and indirect (ingestion) pathways.
- The mitigation of those doses by protective actions (evacuation, sheltering, and post-accident relocation of people; disposal of milk, meat, and crops; and decontamination, temporary interdiction, or condemnation of land and buildings).

- The early fatalities and injuries expected to occur within one year of the accident (early health effects) and the delayed (latent) cancer fatalities and injuries expected to occur over the lifetime of the exposed individuals.

- The off-site costs of short-term emergency response actions (evacuation, sheltering, and relocation), of crop and milk disposal, and of the decontamination, temporary interdiction, or condemnation of land and buildings.

The consequences estimated with the MACCS2 model in terms of the population dose and off-site economic costs for the base case are shown in Table E.1-5. These factors were used to estimate risk by multiplying the frequencies by the consequences. The resultant risk was then expressed as the magnitude of consequences expected per unit time. Table E.1-6 shows the risk measures for the base case and the three evacuation-model sensitivity cases (1.2 m/s evacuation speed, 90% evacuation and 2 hour shorter duration). These were obtained by summing the frequencies multiplied by the consequences over the entire range of distributions. Because the probabilities are on a per reactor-year basis, the averages shown are also on a per reactor-year basis.

Table E.1-1, ANO-2 Core Inventory [1]

Nuclide	Core inventory (becquerels)	Nuclide	Core inventory (becquerels)
Cobalt-58	2.86E+16	Tellurium-131M	4.15E+17
Cobalt-60	2.19E+16	Tellurium-132	4.13E+18
Krypton-85	2.20E+16	Iodine-131	2.84E+18
Krypton-85M	1.03E+18	Iodine-132	4.19E+18
Krypton-87	1.88E+18	Iodine-133	6.01E+18
Krypton-88	2.54E+18	Iodine-134	6.60E+18
Rubidium-86	1.67E+15	Iodine-135	5.67E+18
Strontium-89	3.18E+18	Xenon-133	6.02E+18
Strontium-90	1.72E+17	Xenon-135	1.13E+18
Strontium-91	4.09E+18	Cesium-134	3.84E+17
Strontium-92	4.26E+18	Cesium-136	1.17E+17
Yttrium-90	1.84E+17	Cesium-137	2.14E+17
Yttrium-91	3.88E+18	Barium-139	5.57E+18
Yttrium-92	4.28E+18	Barium-140	5.51E+18
Yttrium-93	4.84E+18	Lanthanum-140	5.63E+18
Zirconium-95	4.90E+18	Lanthanum-141	5.17E+18
Zirconium-97	5.11E+18	Lanthanum-142	4.98E+18
Niobium-95	4.63E+18	Cerium-141	5.01E+18
Molybdium-99	5.41E+18	Cerium-143	4.87E+18
Technetium-99M	4.67E+18	Cerium-144	3.02E+18
Ruthenium-103	4.03E+18	Praseodymium-143	4.79E+18
Ruthenium-105	2.62E+18	Neodymium-147	2.14E+18
Ruthenium-106	9.15E+17	Neptunium-239	5.73E+19
Rhodium-105	1.81E+18	Plutonium-238	3.25E+15
Antimony-127	2.47E+17	Plutonium-239	7.33E+14
Antimony-129	8.76E+17	Plutonium-240	9.24E+14
Tellurium-127	2.39E+17	Plutonium-241	1.56E+17
Tellurium-127M	3.16E+16	Americium-241	1.03E+14
Tellurium-129	8.22E+17	Curium-242	3.93E+16
Tellurium-129M	2.17E+17	Curium-244	2.30E+15

[1] Reference E.1-1.

Table E.1-2, ANO-2 RELEASE FRACTION BY NUCLIDE GROUP [2]

Release Mode [3]	Frequency [4]	Xenon/ Krypton	Iodine	Cesium	Tellurium	Strontium
A1	4.22E-08	9.20E-01	1.07E-04	9.02E-05	2.99E-05	4.17E-07
A2	8.73E-10	9.20E-01	4.29E-03	3.61E-03	1.20E-03	1.67E-05
B1	1.46E-13	9.20E-01	2.64E-04	2.15E-04	5.99E-05	8.35E-07
B2-L	7.48E-11	9.20E-01	9.96E-03	8.18E-03	2.40E-03	3.34E-05
B2-R	3.95E-12	9.20E-01	9.96E-03	8.18E-03	2.40E-03	3.34E-05
B3-L	7.06E-10	9.20E-01	2.64E-04	2.15E-04	5.99E-05	8.35E-07
B3-R	7.06E-10	9.20E-01	2.64E-04	2.15E-04	5.99E-05	8.35E-07
B4-L	7.32E-09	9.20E-01	9.96E-03	8.18E-03	2.40E-03	3.34E-05
B4-R	1.05E-09	9.20E-01	9.96E-03	8.18E-03	2.40E-03	3.34E-05
B5-L	7.06E-10	9.20E-01	8.82E-04	4.76E-04	1.13E-04	1.57E-06
B5-R	7.06E-10	9.20E-01	8.82E-04	4.76E-04	1.13E-04	1.57E-06
B6-L	3.19E-07	9.20E-01	4.04E-03	2.29E-03	2.03E-04	2.83E-06
B6-R	1.74E-08	9.20E-01	4.04E-03	2.29E-03	2.03E-04	2.83E-06
BP-D3A	3.57E-08	7.44E-01	2.10E-02	2.13E-02	1.51E-02	1.38E-04
BP-D3B	3.57E-08	9.20E-01	2.18E-01	2.21E-01	5.86E-02	1.14E-03
BP-E5A	8.96E-09	8.24E-01	2.12E-02	2.14E-02	1.54E-02	1.38E-04
BP-E5B	8.96E-09	1.00E+00	2.23E-01	2.26E-01	6.56E-02	1.14E-03
BP-E6A	2.98E-09	8.24E-01	2.84E-02	2.60E-02	2.43E-02	1.42E-04
BP-E6B	3.30E-07	1.00E+00	3.89E-01	3.43E-01	2.58E-01	1.16E-03
C1-L	4.71E-09	1.00E+00	6.39E-04	4.85E-04	1.06E-03	8.35E-07
C1-R	9.16E-10	1.00E+00	6.39E-04	4.85E-04	1.06E-03	8.35E-07
C2-L	8.74E-10	1.00E+00	1.03E-02	8.45E-03	4.26E-03	3.34E-05
C2-R	7.13E-10	1.00E+00	1.03E-02	8.45E-03	4.26E-03	3.34E-05
C3-L	3.13E-06	1.00E+00	6.65E-04	5.04E-04	1.06E-03	8.35E-07
C3-R	1.66E-07	1.00E+00	6.65E-04	5.04E-04	1.06E-03	8.35E-07
C4-L	5.46E-07	1.00E+00	2.12E-02	1.63E-02	3.03E-02	3.34E-05
C4-R	2.94E-08	1.00E+00	2.12E-02	1.63E-02	3.03E-02	3.34E-05
C5-L	3.91E-07	1.00E+00	1.26E-03	7.46E-04	1.11E-03	1.57E-06
C5-R	2.12E-08	1.00E+00	1.26E-03	7.46E-04	1.11E-03	1.57E-06
C6-L	5.08E-07	1.00E+00	1.53E-02	1.04E-02	2.81E-02	2.83E-06

[2] Reference E.1-2.

[3] Release Modes notation:

A, B, C = late releases.
BP = bypass release modes
D, E = early releases
-R = containment rupture
-L = containment leak

[4] Release Mode frequency per reactor year.

Table E.1-2, ANO-2 RELEASE FRACTION BY NUCLIDE GROUP [2]

Release Mode [3]	Frequency [4]	Xenon/ Krypton	Iodine	Cesium	Tellurium	Strontium
C6-R	2.73E-08	1.00E+00	1.53E-02	1.04E-02	2.81E-02	2.83E-06
D1-L	1.61E-11	9.20E-01	1.41E-03	1.18E-03	3.81E-04	5.31E-06
D1-R	2.62E-09	9.20E-01	5.70E-03	4.79E-03	1.58E-03	2.20E-05
D2-L	3.10E-08	9.20E-01	5.60E-02	4.69E-02	1.52E-02	2.13E-04
D2-R	3.20E-08	9.20E-01	2.28E-01	1.91E-01	6.32E-02	8.80E-04
D3-L	3.49E-08	9.20E-01	5.11E-03	2.73E-03	7.19E-04	1.00E-05
D3-R	5.47E-08	9.41E-01	5.62E-02	3.66E-02	2.36E-02	3.41E-03
D4-L	1.36E-06	9.41E-01	2.02E-02	1.25E-02	6.27E-03	8.30E-04
D4-R	1.36E-06	9.41E-01	7.54E-02	4.70E-02	2.60E-02	3.44E-03
E1-L	7.06E-10	1.00E+00	2.66E-03	2.08E-03	2.73E-03	5.31E-06
E1-R	7.06E-10	1.00E+00	1.10E-02	8.57E-03	8.61E-03	2.20E-05
E2-L	1.04E-09	1.00E+00	5.72E-02	4.78E-02	1.90E-02	2.13E-04
E2-R	1.12E-09	1.00E+00	2.33E-01	1.95E-01	7.63E-02	8.80E-04
E3-L	9.60E-10	1.00E+00	2.75E-03	2.15E-03	2.37E-03	5.31E-06
E3-R	4.19E-08	1.00E+00	1.13E-02	8.84E-03	8.61E-03	2.20E-05
E4-L	2.41E-07	1.00E+00	9.35E-02	7.39E-02	7.11E-02	2.13E-04
E4-R	2.56E-07	1.00E+00	3.85E-01	3.05E-01	2.60E-01	8.80E-04
E5-L	9.36E-09	1.00E+00	6.36E-03	3.63E-03	2.71E-03	1.00E-05
E5-R	1.44E-08	1.00E+00	6.01E-02	3.94E-02	2.87E-02	3.41E-03
E6-L	5.15E-07	1.00E+00	4.77E-02	3.23E-02	4.73E-02	8.30E-04
E6-R	5.19E-07	1.00E+00	1.91E-01	1.30E-01	1.71E-01	3.44E-03

[2] Reference E.1-2.

[3] Release Modes notation:

A, B, C = late releases.
BP = bypass release modes
D, E = early releases
-R = containment rupture
-L = containment leak

[4] Release Mode frequency per reactor year.

Table E.1-3
ANO-2 Regional Population Distribution
(With Emergency Zone Transient Population)

	0-10 Miles	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	Totals
N	2318	1341	216	2020	9045	14940
NNE	1999	3311	216	1352	3130	10008
NE	5954	5709	460	2099	4353	18575
ENE	7909	6843	3159	2922	16774	37607
E	15451	9250	4773	9121	28912	67507
ESE	57546	16111	17261	20780	135403	247101
SE	15779	2635	3643	11593	8724	42374
SSE	9913	3667	2751	134	31836	48301
S	7514	7409	3653	421	5092	24089
SSW	3903	6183	5975	673	1999	18733
SW	1146	2838	3251	1483	1231	9949
WSW	986	604	2204	10154	14441	28389
W	940	4918	15688	10391	16246	48183
WNW	4044	4570	10964	22413	10415	52406
NW	5509	29238	5975	1767	3472	45961
NNW	2235	3485	1644	1255	2435	11054
Totals	143146	108112	81833	98578	293508	725177

Table E.1-4, MACCS2 Economic Parameters

Variable	Description	Value
DPRATE	Property depreciation rate (per yr)	0.2
DSRATE	Investment rate of return (per yr)	0.12
EVACST	Daily cost for a person who has been evacuated ($/person-day)	43.05
POPCST	Population relocation cost ($/person)	7967.12
RELCST	Daily cost for a person who is relocated ($/person-day)	43.05
CDFRM0	Cost of farm decontamination for various levels of decontamination ($/hectare)	896.59 1992.49
CDNFRM	Cost of non-farm decontamination per resident person for various levels of decontamination ($/person)	4781.42 12754.28
DLBCST	Average cost of decontamination labor ($/man-year)	55792.80
VALWF0	Value of farm wealth ($/hectare)	4547.23
VALWNF	Value of non-farm wealth ($/person)	126107.80

Table E.1-5, Summary of Off-site Consequence Results for Each Release Category

Table E.1-5		
Release Category	**Population Dose (Sieverts)**	**Total Economic Cost (Dollars)**
A1	250	1.07E+07
A2	2410	3.56E+08
B1	494	2.53E+07
B2-L	3630	6.47E+08
B2-R	3630	6.47E+08
B3-L	494	2.53E+07
B3-R	494	2.53E+07
B4-L	3630	6.47E+08
B4-R	3630	6.47E+08
B5-L	827	6.96E+07
B5-R	827	6.96E+07
B6-L	1890	2.67E+08
B6-R	1890	2.67E+08
BP-D3A	5150	1.18E+09
BP-D3B	12200	3.46E+09
BP-E5A	5180	1.18E+09
BP-E5B	12500	3.48E+09
BP-E6A	5700	1.35E+09
BP-E6B	18900	3.93E+09
C1-L	862	6.96E+07
C1-R	862	6.96E+07
C2-L	3710	6.61E+08
C2-R	3710	6.61E+08
C3-L	888	7.05E+07
C3-R	888	7.05E+07
C4-L	5410	1.05E+09
C4-R	5410	1.05E+09

Table E.1-5

Release Category	Population Dose (Sieverts)	Total Economic Cost (Dollars)
C5-L	1080	1.12E+08
C5-R	1080	1.12E+08
C6-L	4360	7.84E+08
C6-R	4360	7.84E+08
D1-L	1320	1.82E+08
D1-R	2480	4.51E+08
D2-L	7170	2.23E+09
D2-R	14400	3.31E+09
D3-L	2070	3.14E+08
D3-R	6960	1.77E+09
D4-L	4670	9.17E+08
D4-R	7990	1.97E+09
E1-L	1800	2.66E+08
E1-R	3630	6.41E+08
E2-L	7280	2.25E+09
E2-R	14700	3.34E+09
E3-L	1830	2.73E+08
E3-R	3670	6.53E+08
E4-L	8350	2.82E+09
E4-R	22800	3.82E+09
E5-L	2400	3.86E+08
E5-R	7270	1.84E+09
E6-L	6890	1.80E+09
E6-R	13700	3.02E+09

Table E.1-6, Risk Measures

	Population Dose (Rem)	Economic Cost ($)	Population Dose (% increase from base case)	Economic Cost (% increase from base case)
Base Case	1.723	3385	----	-----
1.2 m/s evacuation speed	1.568	3385	-9.0%	0.0%
90% evacuation	1.773	3364	2.8%	-0.6%
2 hour shorter duration	1.737	3394	0.81%	0.25%

E.1.4 References

E.1-1 *Code Manual for MACCS2, User's Guide*, D. Chanin and M. L. Young, Technadyne Engineering Consultants and Sandia National Laboratories for U. S. Nuclear Regulatory Commission and U. S. Department of Energy, SAND97-0594, NUREG/CR-6613, Vol. 1, May 1998.

See also,

MELCOR Accident Consequence Code System (MACCS), Model Description, H. N. Jow, et. al., Sandia National Laboratories for U. S. Nuclear Regulatory Commission, SAND86-1562, Vol. 2, NUREG/CR-4691, February 1990.

Evaluation of Severe Accident Risks: Quantification of Major Input Parameters, MACCS Input, J. L. Sprung, et. al., Sandia National Laboratories for the U. S. Nuclear Regulatory Commission, NUREG/CR-4551, Vol. 2, Rev. 1, Part 7, December 1990.

E.1-2 *ANO-2 Probabilistic Risk Assessment (PRA) Individual Plant Examination (IPE) Submittal*, Report Number 94-R-2005-01, March 1994.

E.1-3 *Evaluation of Severe Accident Risks: Surry 1 Main Report*, NUREG/CR-4551, Vol. 3, Rev. 1, Part 1, Breeding, R. J., et al, October 1990.

E.1-4 *1996 Hourly Precipitation Data for Clarksville 6 NE COOP ID 031457*, NCDC (National Climatic Data Center, National Oceanic and Atmospheric Administration), Order Num. 6394, May 7, 1999.

E.1-5 *SECPOP90: Sector Population, Land Fraction, and Economic Estimation Program,* NUREG/CR-6525, Humphreys, S. L., et al, September, 1997.

E.1-6 *Census of Population and Housing, 1990: Public Law (P. L.) 94-171, Data Technical Documentation*, CD – ROM set, BOC (Bureau of the Census, U. S. Dept. of Commerce), 1991.

E.1-7 *ANO Emergency Plan*, Entergy Operations, Inc., Rev. 28, January 15, 2003.

E.1-8 *Bureau of Labor Statistics - Consumer Price Index*, www.bls.gov/cpi.

E.1-9 *Safety Evaluation Report Related to the License Renewal of Arkansas Nuclear One, Unit 1*, NUREG-1743, April 2001.

E.1-10 *Arkansas Nuclear One 2000 Census Data*, letter from B. West, FTN Associates, Ltd. To R. Buckley, Entergy Services, Inc., FTN 6045-062, February 5, 2003.

E.1-11 *Arkansas Nuclear One, Unit No. 2 – Issuance of Amendment RE: Increase in Licensed Power Level (Tac. No. MB0789)*, letter from T. W. Alexion to C. G. Anderson, 2CNA040207, April 24, 2002.

E.2 EVALUATION OF SAMA CANDIDATES

This section describes the generation of the initial list of potential SAMA candidates, screening methods, and the analysis of the remaining SAMA candidates.

E.2.1 SAMA List Compilation

A list of SAMA candidates was developed by reviewing industry documents and considering plant-specific enhancements not identified in published industry documents. Since ANO-2 is a conventional Combustion Engineering nuclear power reactor, considerable attention was paid to the SAMA candidates from SAMA analyses for other CE plants. Attention was also paid to the generation and screening of plant-specific enhancements documented in the ANO-1 SAMA evaluation. Industry documents reviewed include the following:

Calvert Cliffs Nuclear Power Plant SAMA Analysis (Reference E.2-1)

Combustion Engineering System 80+ SAMDA Analysis (Reference E.2-2)

Arkansas Nuclear One Unit 1 SAMA Evaluation (Reference E.2-3)

The above documents represent a compilation of SAMA candidates developed from other industry documents. These sources of industry documents include:

Watts Bar Nuclear Plant Unit 1 PRA/IPE submittal

Limerick SAMDA cost estimate report

NUREG-1437 description of Limerick SAMDA

NUREG-1437 description of Comanche Peak SAMDA

Watts Bar SAMDA submittal

TVA response to NRC's RAI on the Watts Bar SAMDA submittal

Westinghouse AP600 SAMDA

Safety Assessment Consulting presentation by Wolfgang Werner at the NUREG-1560 conference

NRC IPE Workshop – NUREG-1560 NRC Presentation

NUREG-0498, Supplement 1, Section 7

NUREG/CR-5567, PWR Dry Containment Issue Characterization

NUREG-1560, Volume 2, NRC Perspectives on the IPE Program

NUREG/CR-5630, PWR Dry Containment Parametric Studies

NUREG/CR-5575, Quantitative Analysis of Potential Improvements for the Dry PWR Containment

ICONE paper by C. W. Forsberg, et. al., on a core melt source reduction system

In addition to SAMA candidates from review of industry documents, additional SAMA candidates were obtained from plant-specific sources, such as the ANO-2 Individual Plant Examination (IPE) (Reference E.2-4) and Individual Plant Evaluation of External Events (IPEEE) (Reference E.2-5). In both the IPE and IPEEE, several enhancements related to severe accident design performance were recommended. These nineteen enhancements were included in the comprehensive list of SAMA candidates and are listed below.

SAMA Candidates Obtained from the IPE (Reference E.2-4)

CB-22 Provide procedural verification that the shutdown cooling system is secured during startup by local verification that the shutdown cooling suction line isolation valves are closed. This additional check would reduce the potential for an interfacing system LOCA to be introduced through this path due to inadvertent valve mis-positioning resulting from valve failure to stroke properly.

CB-23 Add a procedural requirement to close manual valve 2HPA-2 to ensure that failure of 2SV-8231-2 will not introduce a small containment leak path.

CB-24 The potential exists during a degraded power condition for an unisolated leak path to develop from the containment through the 2" vent header line to the waste gas surge tank (2T17) via valves 2CV-2400-2 and 2CV-2401-1. Should this path be open prior to a degraded power (loss of AC) condition, the degraded power procedure could be used to ensure that these valves are closed, and to manually close 2CV-2401-1 or manual valve 2CVH-8, which is in series with these valves. This SAMA would increase the probability of successful containment isolation when required.

CB-25 Reorient 2CV-5254-2 to oppose potential flow from the reactor coolant system to reduce the potential of an interfacing system LOCA through a ruptured reactor coolant pump seal cooler tube. Increase component cooling water relief capacity to minimize the likelihood of the component cooling water piping breaking between 2CV-5255-1 and the containment penetration.

CW-23 Enhance loss of service water procedures to improve the ability to avoid unnecessary low pressure safety injection and containment spray pump overheating failures that can minimize the benefit of restoring service water.

EV-31 Remove check valve internals to improve the potential for cooling communication between molten core debris in the bottom of the cavity and water on the containment floor. Improved cooling of a failed core would decrease the potential for a post severe accident off-site release.

FW-17 Enhance emergency operating procedures to place emergency feedwater flow control valves in an open position once it has been determined that main steam isolation signal conditions do not exist. If the outboard flow control valves from both the motor-driven and turbine-driven pumps were in a full open position upon loss of power supply, the potential for loss of flow to both steam generators would be minimized.

OT-09 Flood fuel transfer tube in the event of core damage. This would reduce the potential for a high-temperature induced failure of the fuel transfer tube flange seals during accidents involving high pressure melt ejection. This action would help cool the transfer tube flange and its seals and would help scrub fission products escaping through failed seals.

SAMA Candidates Obtained from the IPEEE (Reference E.2-5)

IPEEE-01 Bolt control cabinets 2C02, 2C03, 2C04, 2C09, 2C16, 2C17, 2C21, 2C21-1, 2C22, and 2C23 together.

IPEEE-02 Ensure that the doors to cabinet 2C21-2 latch properly.

IPEEE-03 Connect back-to-back motor control centers 2B-54 & 2B-64 so they respond together during an earthquake.

IPEEE-04 Inspect the rear anchorage of 480V load centers.

IPEEE-05 Provide an additional anchorage for control cabinet 2C80.

IPEEE-06 Ensure the protection of control cabinet 2C80 during a seismic event. Control cabinet 2C80 has an adjacent instrumentation cabinet that could topple during an earthquake. Additionally, a fire extinguisher is nearby on a fairly short hook that could fall and become a potential missile.

IPEEE-07 Move breaker adjustment cranks from 480V load centers 2B-5 & 2B-6.

IPEEE-08 Close open S-hooks on light fixtures above motor control centers 2B-51 & 2B-61.

IPEEE-09 Further investigate the calculated value for high confidence low probability of failure (<0.3g) for the emergency diesel fuel tanks 2T-57A & 2T-57B.

IPEEE-10 Tighten doors of control cabinet 2C-16 so they do not rattle during an earth quake.

IPEEE-11 Further investigate the calculated value for high confidence low probability of failure (<0.3g) for inverters 2A-3 and 2A-4.

The current ANO-2 PSA model was also used to identify plant-specific modifications for inclusion in the comprehensive list of SAMA candidates. The top 100 cut sets from the PSA model were reviewed for patterns that could be addressed through a potential enhancement to the plant. Sixteen postulated modifications were developed, included in the list of SAMA candidates, and listed below.

SAMA Candidates Obtained from the Current PSA Model

AC/DC-24 Create the ability to automatically transfer battery charger/eliminator 2D31B to an alternate power source upon demand. This SAMA would reduce the potential for human error in transferring battery charger 2D31B to an alternate power source.

CB-26 Change plant operating procedures to isolate the low pressure safety injection line following the failure of series system check valves. Also, enhance operator training on coping with interfacing system LOCAs resulting from reactor coolant pump seal cooler tube ruptures.

CC-18 Prevent plugging of the containment sump strainers by modifying the existing strainers and adding additional strainer area.

CC-19 Provide an additional flow path from the refueling water tank to the high-pressure safety injection system through a diversified suction flow path check valve. This SAMA would reduce the potential for common cause failure of refueling water tank flow path check valves.

CC-20 Replacing either containment sump valve 2CV-5649-1 or 2CV-5650-2 with an air-operated valve. This would reduce the potential for common cause failure of these valves preventing adequate core cooling.

CC-21 Reduce the potential for common cause failure of high-pressure safety injection motor-operated valves by replacing redundant train valve actuators with diversified valve actuators.

CC-22 Reduce the potential of common cause failure of two or more recirculation actuation signal and engineered safety features actuation signal actuation relays (e.g., K104A/B, SSR-1/3A, etc.) This modification would replace existing relays with relays of a diverse design.

CC-23 Increase the reliability of automatic recirculation swap over. This modification would install an additional level transmitter and change the recirculation actuation logic from 2-out-of-4 to 2-out-of-5.

CC-24 Provide a bypass flow path with a normally open motor-operated control valve around the safety injection tank discharge control valves. This modification would increase the probability of injection if the motor-operated control valves fail closed.

CW-09 Provide an additional diversified service water pump. Decrease the frequency of core damage due to a loss of service water by installing an additional service water pump with an independent diesel generator. This modification also requires that one of the remaining service water pumps be supplied with an independent diesel to reduce the potential for common cause failure of all of the service water pumps.

CW-24 Provide the ability to automatically trip the reactor coolant pumps on a loss of component cooling water. This SAMA would reduce the potential for a seal LOCA following a loss of component cooling water by reducing the reliance on operator action to trip the reactor coolant pumps.

CW-25 Add a redundant valve in series with 2CV-1530-1 on service water header 1 (and 2CV-1531-2 on service water header 2). This SAMA would increase the reliability of isolation if the isolation valves supplying the component cooling water heat exchangers and main chillers fail to close upon demand.

CW-26 Reduce the failure frequency of the service water system. This SAMA would increase the inspection and cleaning frequency of the service water pump discharge filters, reducing the probability of a common cause failure.

CW-27 Reduce the failure frequency of the service water system. This SAMA would install backwash filters in place of the existing strainers, reducing the probability of a common cause failure.

EV-30 Reduce the potential for common cause failure of containment spray system motor-operated valves by replacing redundant train motor-operated valve actuators with diverse valve actuators.

FW-19 Create the ability to automatically align emergency feedwater/auxiliary feedwater suction to the other condensate storage tank on low-low level of 2T-41A or 2T-41B. This modification would reduce the potential for a loss of feedwater.

The comprehensive list contained a total of 192 SAMA candidates.

E.2.2 Qualitative Screening of SAMA Candidates

The purpose of the preliminary SAMA screening was to eliminate from further consideration enhancements that were not viable for implementation at ANO-2. Potential SAMA candidates were screened out if they modified features not applicable to ANO-2, if they had already been implemented at ANO-2, or if they were similar in nature and could be combined with another SAMA candidate to develop a more comprehensive or plant-specific SAMA candidate.

During this process, 99 of the 192 original SAMA candidates were eliminated, leaving 93 SAMA candidates for further analysis. These 93 improvements are listed in Table E.2-1.

The final screening process involved identifying and eliminating those items whose cost exceeded their benefit as described below. Table E.2-1 provides a description of each of the 93 SAMA candidates.

E.2.3 Final Screening of SAMA Candidates

A benefits analysis was performed on each of the remaining SAMA candidates. The benefit was defined as the sum of the dollar equivalents for each severe accident impact (off-site exposure, off-site economic costs, occupational exposure, and on-site economic costs). If the expected cost exceeded the estimated benefit, the SAMA was not considered cost-beneficial.

Implementation of each SAMA candidate would change the severe accident risk (i.e., a change in frequency or consequence of severe accidents). Bounding evaluations (or analysis cases) were performed to address specific SAMA candidates or groups of similar SAMA candidates. These analysis cases overestimated the benefit and thus were conservative calculations. For example, one SAMA candidate suggested installing a digital large break LOCA protection system. The bounding calculation estimated the benefit of this improvement by total elimination of risk due to large break LOCAs (see analysis case LBLOCA, below). This calculation obviously overestimated the benefit, but if the inflated benefit indicated that the SAMA candidate was not cost-beneficial then the purpose of the analysis was satisfied. A description of the analysis cases used in the evaluation follows.

AIR

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the plant air compressors were replaced with a more reliable model. Although the proposed SAMA would not completely eliminate air compressor failures, a bounding benefit was estimated by setting the plant air compressor failure events to zero. Perfectly reliable air compressors result in minimal benefit. This analysis case was used to model the benefit of SAMA IA-02.

ATWS1

This analysis case was used to estimate the maximum attainable benefit from enhancements related to ATWS coping. For this case, the maximum attainable benefit of ATWS reduction was estimated by multiplying the results of the MAXBENEFIT case by the ratio of the CDF contribution of an ATWS to the total CDF, [(ATWS CDF)/ (Total CDF)*(MAXBENEFIT)]. The ATWS contribution to core damage is 1.59E-6. Elimination of core damage due to an ATWS results in a benefit of approximately $140,000. This analysis case was used to model the benefit of SAMAs AT-01, AT-02 and AT-03.

ATWS2

This analysis case was used to estimate the benefit associated with increasing the charging pump lube oil capacity. The benefit was obtained by multiplying the results of the MAXBENEFIT case by the ratio of the change in the CDF of an ATWS to the total CDF of ANO-2 (i.e., [{ΔATWS CDF/Total CDF}*{MAXBENEFIT}]). The ATWS contribution to core damage is

1.59E-6. The ATWS frequency is derived from three sequence groups: Turbine Trip (1.34E-6/yr), Loss of MFW (1.26E-7/yr), and LOOP (1.25E-7/yr). Examination of the ATWS cut sets (Reference E.2-7) indicates that for top event BW (borated water addition) following turbine trip/loss of MFW, 9.5% of the top event probability is from cut sets that include failure of at least one charging pump. For top event BW following a LOOP, 0.38% of the top event probability is from cut sets that include charging pump failure. To approximate the benefit from this SAMA, these percentages were applied to the ATWS sequence frequencies above. Hence, the revised ATWS CDF (1.45E-6) is an estimate of the fraction of the initial ATWS CDF not associated with charging pump failure. Therefore, the benefit associated with making the charging pumps perfectly reliable has an estimated value of $12,000. This analysis case was used to model the benefit of SAMA CW-07.

BRKR

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if procedures were enhanced to repair or change out failed 4160VAC breakers. Although the proposed SAMA would not eliminate all potential failures of the 4160VAC breakers, a bounding benefit was estimated by removing the 4160VAC breaker gates. Elimination of all 4160V breaker failures results in a benefit of approximately $6,000. This analysis case was used to model the benefit of SAMA AC/DC-15.

CAVITY

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if reactor cavity flooding ability was enhanced. Plant damage state IVKi is dominated by a sequence initiated by a transient event, followed by unsuccessful secondary cooling, successful once-through cooling during the injection mode and failure of HPSI during the recirculation mode as a result of high temperature containment sump water combined with high room temperature. Removal of the internals from check valve 2BS-46 was recommended in the ANO-2 IPE to mitigate this type of sequence. Although the proposed SAMAs would not completely eliminate the potential for such a scenario, a bounding benefit was estimated by removing all risk contribution attributable to this PDS. Elimination of core damage attributable to plant damage state IVKi results in a benefit of approximately $17,000. This analysis case was used to model the benefit of SAMAs EV-15, EV-16, EV-17, and EV-31.

CBPEN

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the station blackout procedure included a requirement to close manual valve 2HPA-2. PDS SBOu is composed of station blackout events with unsuccessful containment isolation. In this scenario, combinations of DC and AC power failures could result in failure of 2SV-8231-2 to close or remain closed. Removal of this PDS is the modeling equivalent of manually closing 2HPA-2, which was recommended in the ANO-2 IPE to ensure that failure of 2SV-8231-2 will not introduce a containment leak path. Although the proposed SAMA would not completely eliminate the potential for such a scenario, a bounding benefit was estimated by eliminating this PDS. Elimination of all core damage attributable to plant damage state SBOu results in a benefit of approximately $200. This analysis case was used to model the benefit of SAMA CB-23.

CST

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the ability to automatically align EFW/AFW suction to the alternate condensate storage tank was installed. Although the proposed SAMA would not completely eliminate the potential failures, a bounding benefit was estimated by removing the human failure event for suction alignment. Perfectly reliable re-alignment of EFW/AFW suction to the alternate condensate storage tank results in a benefit of approximately $10,000. This analysis case was used to model the benefit of SAMA FW-19.

DCPWR

This analysis case was used to evaluate plant modifications that would increase the availability of Class 1E DC power (e.g., increased battery capacity or the installation of a diesel-powered generator that would effectively increase battery capacity). Although the proposed SAMAs would not completely eliminate the potential failure, a bounding benefit was estimated by removing the battery discharge events and battery failure events. Station battery capacity of 24 hours results in a benefit of approximately $34,000. This analysis case was used to model the benefit of SAMAs AC/DC-04, AC/DC-05, AC/DC-10, AC/DC-12, and AC/DC-24.

EDGCOOL

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if a back-up source of EDG cooling was installed. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing EDG service water cooling gates. Perfectly reliable EDG cooling results in a benefit of approximately $20,000. This analysis case was used to model the benefit of SAMA AC/DC-19.

EFW

This analysis case was used to evaluate the change in the plant risk profile that would be achieved following modifications making EFW more reliable, such as installing an independent diesel for the condensate storage tank makeup pumps or switching EFW room cooling power to station batteries in a station blackout. Although none of the proposed changes would completely eliminate EFW failures, a bounding benefit was estimated by removing all EFW system failure gates. A perfectly reliable EFW system results in a benefit of approximately $104,000. This analysis case was used to model the benefit of SAMAs FW-13 and HV-05.

EFWCV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved by modifying procedures directing operators to open the emergency feedwater flow control valves to the steam generators following failure due to power supply or signal failure.

Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by setting the corresponding human failure event to zero. Elimination of operator failure to open the emergency feedwater flow control valves results in a benefit of approximately $17,000. This analysis case was used to model the benefit of SAMA FW-17.

ESFASRELAY

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the engineered safety features actuation system actuation and solid state relays were replaced with diverse designs. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by eliminating the ESFAS actuation relay common cause failure events. Elimination of all core damage due to common cause failure of engineered safety features actuation and solid state relays results in a benefit of approximately $15,000. This analysis case was used to model the benefit of SAMA CC-22.

FDW

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if a digital feedwater upgrade was installed or modifications were made to cap the downstream piping of normally closed CCW drain and vent valves. Although none of the proposed changes would completely eliminate MFW failures, a bounding benefit was estimated by removing the loss of feedwater initiating event and MFW failure gates. Elimination of all core damage due to loss of feedwater results in a benefit of approximately $112,000. This analysis case was used to model the benefit of SAMA CW-01 and FW-01.

FILTER

This analysis case was used to evaluate the change in the plant risk profile that would be achieved by increasing the inspection frequency of the service water pump discharge filters or replacing them with backwash filters. Although none of the proposed changes would completely eliminate service water pump discharge filter failures, a bounding benefit was estimated by removing the service water pump discharge filter common cause failure event. Elimination of all common cause failures of service water pump discharge filters results in a benefit of approximately $100,000. This analysis case was used to model the benefit of SAMAs CW-26 and CW-27.

HPSICV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved by providing an additional flow path from the refueling water tank to the high pressure safety injection system. Although the proposed SAMA would not completely eliminate the potential failure, a bounding benefit was estimated by removing the HPSI system check valve failure events. Elimination of all core damage due to failure of the high-pressure safety injection flow path check valves results in a benefit of approximately $29,000. This analysis case was used to model the benefit of SAMA CC-19.

HPSIMOV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved by providing actuator diversity for the MOVs in the HPSI system. Although the proposed SAMA would not completely eliminate this potential failure, a bounding benefit was estimated by removing the HPSI MOV common cause failure event. Elimination of all core damage due to common cause failure of the high-pressure safety injection valves results in a benefit of approximately $22,000. This analysis case was used to model the benefit of SAMA CC-21.

HVAC

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if procedures were developed for temporary HVAC. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing the shutdown heat exchanger room cooling failure gates. Perfectly reliable shutdown heat exchanger room cooling results in a benefit of approximately $174,000. This analysis case was used to model the benefit of SAMAs HV-03.

ISLOCA

This analysis case was used to evaluate the change in the plant risk profile that would be achieved by reducing the probability or consequences of an ISLOCA event. Although none of the proposed changes would completely eliminate the occurrence or impact of ISLOCA events, a bounding benefit was estimated by removing the ISLOCA event. Elimination of all core damage from ISLOCA results in a benefit of approximately $86,000. This analysis case was used to model the benefit of SAMAs CB-13, CB-14, CB-19, and CB-20.

ISLOCAHEP

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if procedures, associated with operation and maintenance of systems interfacing the reactor coolant system, were enhanced. Although the proposed SAMA would not completely eliminate the potential for human failures, a bounding benefit was estimated by assuming perfect human reliability in the operation and maintenance of the systems interfacing the RCS. Elimination of all human error associated with an interfacing system LOCA results in a benefit of approximately $64,000. This analysis case was used to model the benefit of SAMA CB-26.

LBLOCA

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if a digital large break LOCA (LBLOCA) protection system was installed. Although the proposed change would not completely eliminate the potential for a LBLOCA, a bounding benefit was estimated by removing the LBLOCA initiating event. Elimination of all core damage due to large LOCAs results in a benefit of approximately $24,000. This analysis case was used to model the benefit of SAMA OT-07.

LOCCW

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the ability to cool the shutdown cooling heat exchangers was improved or an additional CCW pump was installed. Although the proposed SAMAs would not completely eliminate the potential for a loss of component cooling water, a bounding benefit was estimated by removing the component cooling water header failure gates. Elimination of all core damage due to loss of the component cooling water system results in a benefit of approximately $76,000. This analysis case was used to model the benefit of SAMAs CW-15 and CW-22.

LOOP

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the reliability of the Class 1E power distribution system was improved. Although none of the proposed changes would reduce the LOOP frequency to zero, a bounding benefit was estimated by removing the LOOP initiating event. Elimination of all loss of off-site power initiators results in a benefit of approximately $39,000. This analysis case was used to model the benefit of SAMAs AC/DC-02, AC/DC-09, AC/DC-13, AC/DC-20, AC/DC-21, and AC/DC-22.

LOOPREC

This analysis case was used to evaluate the change in the plant risk profile which would be achieved if the plant recovery steps following a station blackout were emphasized through enhanced training and procedural guidance. Although the proposed SAMA would not ensure instantaneous recovery of on-site equipment during a LOOP, a bounding benefit was estimated by removing events for LOOP non-recovery factors with one or more run failures.

It is difficult to separate the human element from the equipment failure element in the loss of off-site power recovery model. These particular recoveries are used for those cut sets that involved convolution of the mission time failure model with the LOOP recovery time model. In essence, removing these events is equivalent to assuming that none of the LOOP cut sets with time-dependent failures occur. This approximates a "perfect" operator that ensures no additional failures occur, after the initial transient, before off-site power is recovered. This is a very conservative treatment because it is obviously beyond the power of the operators to completely reduce the equipment run-time failure probability to zero or recover off-site power instantly.

Instantaneous recovery of on-site equipment during a loss of off-site power event results in a benefit of approximately $34,000. This analysis case was used to model the benefit of SAMA AC/DC-16.

LOSW

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if an additional diversified service water pump was installed, or if the ECCS pump motors were replaced with air cooled motors. Although the proposed SAMAs would not completely eliminate the potential for core damage due to a loss of the service water, a bounding benefit was estimated by removing service water pump train failure events.

Elimination of all core damage due to loss of service water results in a benefit of approximately $202,000. This analysis case was used to model the benefit of SAMAs CW-09 and CW-13.

LOSWHEP

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if procedures following loss of service water were enhanced. Also, since the results of this analysis case were deemed conservatively representative of other plant support systems, it was used to evaluate the change in the plant risk profile that would be achieved if procedures for other plant support systems were enhanced. Although the proposed SAMAs would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing all service water human failure events. Perfectly reliable recovery of service water results in a benefit of approximately $25,000. This analysis case was used to model the benefit of SAMAs CW-06, CW-21, and CW-23.

MAXBENEFIT

This analysis case was used to determine the maximum benefit attainable by removing all severe accident risk associated with the operation of ANO-2 (i.e., eliminating all contributors to core damage). This analysis case was used to evaluate SAMA candidates suggesting installation of new systems or trains, such as an additional HPSI pump with independent diesel or passive secondary side coolers. Elimination of all core damage results in a benefit of approximately $632,000. This analysis case was used to model the benefit of SAMAs CC-01, CC-02, CC-07, CC-14, FW-15, FW-18, OT-02 and OT-06.

OFFSITE

This analysis case was used to assess the total elimination of all off-site release from the plant following an accident resulting in degradation of the reactor core. A number of the SAMAs are associated with reducing the magnitude or consequences of an off-site release. Although the proposed modifications would not be expected to reduce the actual off-site consequences to zero this bounding case estimated the maximum benefit attainable by totally eliminating off-site release. This case is equal to the total off-site benefit of the MAXBENEFIT case. Elimination of all off-site releases results in a benefit of approximately $178,000. This analysis case was used to model the benefit of SAMAs CB-07, EV-02, EV-04, EV-05, EV-07, EV-08, EV-09, EV-10, EV-11, EV-12, EV-19, EV-20, EV-21, EV-22, EV-23, EV-25, EV-26, EV-27, EV-28 and EV-29.

RASLEVEL

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if an additional RAS level transmitter was installed and the logic changed from 2-out-of-4 to 2-out-of-5. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing the RAS level transmitter failure events. Elimination of all core damage due to failure of the recirculation actuation signal level transmitters results in a benefit of approximately $5,000. This analysis case was used to model the benefit of SAMA CC-23.

SEALLOCA

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the reactor coolant pumps automatically tripped on a loss of CCW, if the reactor coolant pump seals were improved, or if an independent reactor coolant pump seal injection system was installed. Although the proposed SAMAs would not completely eliminate the potential for a seal LOCA, a bounding benefit was estimated by removing the reactor coolant pump seal LOCA gate. Elimination of all seal LOCAs results in a benefit of approximately $71,000. This analysis case was used to model the benefit of SAMAs CW-10, CW-11, CW-14, and CW-24.

SGTR

This analysis case was used to evaluate modifications that would reduce the frequency of tube ruptures or would improve the ability to mitigate a SGTR. Although none of the proposed changes would reduce the core damage contribution from SGTRs to zero, a bounding benefit was estimated by removing the SGTR initiating event. Elimination of all steam generator tube ruptures results in a benefit of approximately $25,000. This analysis case was used to model the benefit of SAMAs CB-01, CB-03, CB-04, CB-08, and CB-10.

SIGNAL

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if operator response to inadvertent actuation signals of engineered safety functions was enhanced by additional training. Although the proposed SAMA would not completely eliminate the impact of inadvertent actuation, a bounding benefit was removing all of the gates for spurious actuation of engineered safety functions. Assuming perfect reliability of 120VAC buses results in a benefit of approximately $5,000. This analysis case was used to model the benefit of SAMA AC/DC-06.

SIMOV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if bypass flow paths were provided for all safety injection tank discharge lines. Although the proposed SAMA would not completely eliminate the effects of this potential failure, a bounding benefit was estimated by removing all failures of the safety injection tank discharge MOVs. Elimination of all core damage due to failure of safety injection tank discharge valves results in a benefit of approximately $4,000. This analysis case was used to model the benefit of SAMA CC-24.

SPRAYMOV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the containment spray MOV actuators were diversified. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing the containment spray MOV common cause failure events. Elimination of all core damage due to common cause failure of containment spray valves results in a benefit of approximately $38,000. This analysis case was used to model the benefit of SAMA EV-30.

SUMPMOV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the containment sump motor-operated valves were diversified. Although the proposed SAMA would not completely eliminate the potential failure of containment sump MOVs, a bounding benefit was estimated by removing all containment sump MOV failure events. Elimination of all core damage due to containment sump valve failures results in a benefit of approximately $31,000. This analysis case was used to model the benefit of SAMA CC-20.

SUMPSTRAIN

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if the containment sump strainers were modified to prevent plugging. Although the proposed SAMA would not completely eliminate sump strainer plugging, a bounding benefit was estimated by removing the containment sump strainer failure event. Elimination of sump strainer plugging contribution to core damage results in a benefit of approximately $36,000. This analysis case was used to model the benefit of SAMA CC-18.

SWMOV

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if redundant control valves were placed in series with the service water to CCW isolation valves. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing the service water to CCW isolation valve failure to close event. Elimination of all core damage due to service water to CCW isolation valve failure results in a benefit of approximately $10,000. This analysis case was used to model the benefit of SAMA CW-25.

TDPUMPDC

This analysis case was used to evaluate the change in the plant risk profile that would be achieved if portable generators were used to power the turbine driven emergency feedwater pump controls after station batteries are depleted. Although the proposed SAMA would not completely eliminate the potential for such a failure, a bounding benefit was estimated by removing the DC power gates to the turbine driven emergency feedwater pump logic. Elimination of turbine-driven pump dependence on DC power results in a benefit of approximately $5,000. This analysis case was used to model the benefit of SAMA FW-08.

Values for avoided public and occupational health risk were converted to a monetary equivalent (dollars) via application of the NUREG/BR-0184 (Reference E.2-7) conversion factor of $2,000 per person-rem and discounted to present value. Values for avoided off-site economic costs were also discounted to present value. If the net value of a SAMA was negative, the cost of the enhancement was greater than the benefit and the SAMA was not cost beneficial.

The expected cost of implementation of each SAMA was established from existing estimates of similar modifications combined with engineering judgment. Most of the cost estimates were developed from similar modifications considered in previous performed SAMA and SAMDA analyses. In particular, these cost-estimates were derived from the three major sources including:

Calvert Cliffs SAMA Analysis (Reference E.2-1)

Westinghouse-CE System 80+ SAMDA Analysis (Reference E.2-2)

ANO-1 SAMA Analysis (Reference E.2-3)

The cost estimates did not include the cost of replacement power during extended outages required to implement the modifications, nor did they include contingency costs associated with unforeseen implementation obstacles. Estimates based on modifications that were implemented or estimated in the past were presented in terms of dollar values at the time of implementation (or estimation), and were not adjusted to present-day dollars. In addition, several implementation costs were originally developed for SAMDA analyses (i.e., during the design phase of the plant), and therefore, do not capture the additional costs associated with performing design modifications to existing plants (i.e., reduced efficiency, minimizing dose, disposal of contaminated material, etc.). Therefore, the cost estimates were conservative.

As this analysis focuses on establishing the economic viability of potential plant enhancement when compared to attainable benefit, often detailed cost estimates were not required to make informed decisions regarding the economic viability of a particular modification. Several of the SAMA candidates were clearly in excess of the attainable benefit estimated from a particular analysis case. For less clear cases, engineering judgment was applied to determine if a more detailed cost estimate was necessary to formulate a conclusion regarding the economic viability of a particular SAMA. In most cases, more detailed cost estimates were not required, particularly if the SAMA called for the implementation of a hardware modification. Nonetheless, the cost of all SAMA candidates was conceptually estimated to the point where conclusions regarding the economic viability of the proposed modification could be adequately gauged.

The cost-benefit comparison and disposition of each of the 93 SAMA candidates is presented in Table E.2-1.

E.2.4 Sensitivity Analyses

Several sensitivity analyses were conducted to gauge the impact of assumptions upon the analysis. The benefits estimated for each of these sensitivities are presented in Table E.2-2.

A description of each sensitivity case follows:

Sensitivity Case #1: Repair/Refurbishment

The purpose of this sensitivity case was to investigate the impact of assuming damaged plant equipment is repaired and refurbished following an accident scenario, as opposed to automatically decommissioning the facility following the event. For the purpose of this analysis, the cost of repair and refurbishment over the lifetime of the plant was assumed to be equivalent to 20% of the replacement power cost in accordance with NUREG/BR-0184 (Reference E.2-7). The sensitivity case #1 results for all of the SAMA candidates were lower than the base case results and therefore, lower than the estimated costs.

Sensitivity Case #2: Conservative Discount Rate

The purpose of this sensitivity case was to investigate the sensitivity of each analysis case to the discount rate. The discount rate of 7.0% used in the base case analyses is conservative relative to corporate practices. Nonetheless, a lower discount rate of 5.0% was assumed in this case. The sensitivity case #2 results for a few of the SAMA candidates were slightly higher than the estimated cost. However, due to conservatism in the benefit estimates and the sensitivity case results, and the fact that most of the costs were estimated only to the point of obtaining reasonable assurance that they were higher than the baseline benefit estimate, these SAMA candidates are still not cost effective for ANO-2.

Sensitivity Case #3: Best-Estimate Discount Rate

The purpose of this sensitivity case was to investigate the sensitivity of each analysis case to the discount rate. The discount rate of 7.0% used in the base case analyses is considered conservative. This analysis case uses a higher discount rate of 15%, as suggested by Entergy, as a best estimate rate to investigate the impact on each analysis case. The sensitivity case #3 results for all of the SAMA candidates were lower than the base case results and therefore, lower than the estimated costs.

Sensitivity Case #4: High Estimated Dose (On-Site)

The purpose of this sensitivity case was to investigate the sensitivity of each analysis case to the on-site dose estimates. For the base case analyses, the immediate and long-term on-site dose to plant personnel following a severe accident was assumed to be 3,300 and 20,000 rem respectively. This analysis case assumed high estimated dose values of 14,000 and 30,000 rem for immediate and long-term on-site dose, respectively, as suggested in NUREG/BR-0184 (Reference E.2-7). The sensitivity case #4 results for a few of the SAMA candidates were slightly higher than the estimated cost. However, due to conservatism in the benefit estimates and the sensitivity case results, and the fact that most of the costs were estimated only to the point of obtaining reasonable assurance that they were higher than the base case benefit estimate, these SAMA candidates are still not cost effective for ANO-2.

Sensitivity Case #5: High On-Site Cleanup Cost

The purpose of this sensitivity case was to investigate the sensitivity of each analysis case to the total on-site cleanup cost. For the base case analyses, the total on-site cleanup cost following a severe accident was assumed to be $1,500,000. This analysis case assumed a high estimated on-site cleanup cost of $2,000,000 as suggested in NUREG/BR-0184 (Reference E.2-7). The sensitivity case #5 results for a few of the SAMA candidates were slightly higher than the estimated cost. However, due to conservatism in the benefit estimates and the sensitivity case results, and the fact that most of the costs were estimated only to the point of obtaining reasonable assurance that they were higher than the base case benefit estimate, these SAMA candidates are still not cost effective for ANO-2.

E.2.5 References

E.2-1 Generic Environmental Impact Statement for License Renewal of Nuclear Plants, (regarding Calvert Cliffs Nuclear Power Plant, Units 1 and 2), U.S. Nuclear Regulatory Commission, NUREG-1437, Supplement 1.

E.2-2 Final Safety Evaluation Report Related to the Certification of the System 80+ Design, NUREG 1462, NRC, August 1994.

E.2-3 Arkansas Nuclear One Unit 1 SAMA Analysis, E.A. Krantz, Analysis File Number ANO1 AF-3, Report Number 99-R-1007-01, January 2000.

E.2-4 ANO-2 Probabilistic Risk Assessment (PRA) Individual Plant Examination (IPE) Submittal, Report Number 94-R-2005-01, March 1994.

E.2-5 Individual Plant Examination of External Events/Fires, T.D. Robinson, Report Number 85-E-0053-48, Rev. 2, March 1996

See also:

ANO-2 IPEEE Fire P2 Values, R. Harris, Report Number 95-E-0066-01, Rev. 2, January 1999.

IPEEE High Confidence of Low Probability of Failure (HCLPF) Calculations for ANO-2 Mechanical and Electrical Equipment and Block Walls, Report Number 96-SQ-2001-01, Rev. 1, May 1996.

IPEEE Other Events, Report Number 94-R-0016-01, Rev.1, December 1994.

IPEEE Seismic Margins Assessment (SMA) of Arkansas Nuclear One, Unit 2, Report Number 96-R-2016-02, Rev. 0, May 1996.

USI A-46/IPEEE Horizontal Tank and Heat Exchanger Report and Review, Report Number 95-SQ-2021-02, Rev. 0, September 1996

E.2-6 *SW Pump Strainer Backwash Device*, ER010551R201 Rev. 0, November, 2001.

E.2-7 *Regulatory Analysis Technical Evaluation Handbook*, NUREG/BR-0184, January 1997.

E.2-8 *ANO-2 ATWS Scoping Report*, 89-E-0048-26, Rev 2, December 1997.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO AC/DC POWER RELIABILITY OR AVAILIABILITY								
AC/DC-02	Install a combustion turbine generator	Improve on-site AC power reliability (i.e., decrease the frequency of a station blackout).	6.08%	5.92%	$39,000	$3,350,000	Not Cost Effective	Elimination of all loss of off-site power initiators results in a benefit of $39,000 (analysis case LOOP). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $3,350,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-04	Use fuel cells in lieu of conventional lead-acid batteries	Extend DC power availability during a station blackout event by replacing station batteries with fuel cells that would extend DC power availability to 24 hours.	5.70%	4.25%	$34,000	$2,000,000	Not Cost Effective	Station battery capacity of 24 hours results in a benefit of $34,000 (analysis case DCPWR). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $2,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-05	Provide additional DC battery capability	Ensure longer battery life during a station blackout and consequently reduce exposure to long term station blackout sequences.	5.70%	4.25%	$34,000	>$150,000	Not Cost Effective	Station battery capacity of 24 hours results in a benefit of $34,000 (analysis case DCPWR). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $150,000 per battery bank. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-06	Train operations crew for response to inadvertent actuation signals	Improve the chance of successful response to loss of two 120VAC buses.	0.90%	0.43%	$5,000	$35,000	Not Cost Effective	Assuming perfect reliability of 120VAC buses results in a benefit of $5,000 (analysis case SIGNAL). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO AC/DC POWER RELIABILITY OR AVAILIABILITY								
AC/DC-09	Improve bus cross-tie capability	Improve AC power reliability by installing automatic bus cross-tie capabilities.	6.08%	5.92%	$39,000	$1,119,000	Not Cost Effective	Elimination of all loss of off-site power initiators results in a benefit of $39,000 (analysis case LOOP). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $1,119,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-10	Incorporate alternate battery charging capabilities	Improve DC power reliability by either cross-tying the AC buses, or installing a portable diesel-driven battery charger.	5.70%	4.25%	$34,000	$134,000	Not Cost Effective	Station battery capacity of 24 hours results in a benefit of $34,000 (analysis case DCPWR). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $134,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-12	Replace current station batteries with a more reliable model	Improve DC power reliability by installing more reliable station batteries.	5.70%	4.25%	$34,000	>$150,000	Not Cost Effective	Station battery capacity of 24 hours results in a benefit of $34,000 (analysis case DCPWR). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $150,000 per battery bank. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-13	Create AC power cross tie capability across units at a multi-unit site	Improve AC power reliability by installing AC power cross-tie capabilities between ANO-1 and ANO-2.	6.08%	5.92%	$39,000	>>$39,000	Not Cost Effective	Elimination of all loss of off-site power initiators results in a benefit of $39,000 (analysis case LOOP). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO AC/DC POWER RELIABILITY OR AVAILIABILITY								
AC/DC-15	Develop enhanced procedures to repair or change out failed 4KV breakers	Increase probability of recovery from a failure of breakers that transfer 4.16 kV non-emergency buses from unit station service transformers to system station service transformers. These failures, in conjunction with failure of the diesel generators, lead to loss of emergency AC power.	1.11%	0.59%	$6,000	$35,000	Not Cost Effective	Elimination of all 4160V breaker failures results in a benefit of $6,000 (analysis case BRKR). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-16	Emphasize steps in plant recovery following a station blackout event	Reduce human error associated with recovery of station blackout events through enhanced training and procedural guidance.	5.30%	5.32%	$34,000	$35,000	Not Cost Effective	Instantaneous recovery of on-site equipment during a loss of off-site power event results in a benefit of $34,000 (analysis case LOOPREC). As discussed in Section E.2, the LOOPREC benefit estimate is very conservative. Also, emphasizing recovery of off-site power in operator training may be detrimental to other necessary recovery actions, negating some of the benefit. Thus, the attainable benefit for this SAMA is much less than $34,000. At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO AC/DC POWER RELIABILITY OR AVAILIABILITY								
AC/DC-19	Create a back-up source for diesel cooling	Provide a redundant source of diesel cooling by making the emergency diesel generators air-cooled.	3.15%	3.14%	$20,000	$1,700,000	Not Cost Effective	Perfectly reliable EDG cooling results in a benefit of $20,000 (analysis case EDGCOOL). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $1,700,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-20	Use fire protection systems as a backup for diesel cooling	Provide redundancy for the diesel cooling support systems.	6.08%	5.92%	$39,000	>$497, 000	Not Cost Effective	Elimination of all loss of off-site power initiators results in a benefit of $39,000 (analysis case LOOP). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $497,000 per diesel generator. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-21	Provide a connection to an alternate off-site power source	Increase off-site power redundancy.	6.08%	5.92%	$39,000	>$25,000,000	Not Cost Effective	Elimination of all loss of off-site power initiators results in a benefit of $39,000 (analysis case LOOP). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $25,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AC/DC-22	Implement underground off-site power lines	Improve off-site power reliability, particularly during severe weather.	6.08%	5.92%	$39,000	>$25,000,000	Not Cost Effective	Elimination of all loss of off-site power initiators results in a benefit of $39,000 (analysis case LOOP). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $25,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO AC/DC POWER RELIABILITY OR AVAILIABILITY								
AC/DC-24	Create the ability to automatically transfer battery charger/eliminator 2D31B to an alternate power source upon demand	Reduce the potential for human error in transferring battery charger 2D31B to an alternate power source.	5.70%	4.25%	$34,000	>>$34,000	Not Cost Effective	Station battery capacity of 24 hours results in a benefit of $34,000 (analysis case DCPWR). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO ATWS COPING								
AT-01	Provide alternative ATWS pressure relief valves	Install a system of relief valves to prevent equipment damage from a primary coolant pressure spike during an ATWS sequence. This enhancement would improve equipment availability following an ATWS.	22.2%	Not Estimated	$140,000	$1,000,000	Not Cost Effective	Elimination of core damage due to an ATWS results in a benefit of $140,000 (analysis case ATWS1). The proposed modification would result in only a fraction of this benefit. In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
AT-02	Create a boron injection/shutdown system to backup the mechanical control rods	Create a boron injection system by modifying the reactor coolant pump seal cooling system to inject boron using existing sources of boron and existing piping and valves. This enhancement would provide a redundant means to shut down the reactor.	22.2%	Not Estimated	$140,000	$300,000	Not Cost Effective	Elimination of core damage due to an ATWS results in a benefit of $140,000 (analysis case ATWS1). The proposed modification would result in only a fraction of this benefit. In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $300,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO ATWS COPING								
AT-03	Provide a diverse plant protection system	Provide an additional diversified plant protection system to reduce the frequency of ATWS events (e.g., ATWS mitigation scram actuation circuitry).	22.2%	Not Estimated	$140,000	$3,000,000	Not Cost Effective	Elimination of core damage due to an ATWS results in a benefit of $140,000 (analysis case ATWS1). The proposed modification would result in only a fraction of this benefit. In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $3,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO IDENTIFYING OR COPING WITH CONTAINMENT BYPASS								
CB-01	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage	Perform eddy-current testing on 100% of the steam generator tubes during each refueling outage to reduce the frequency of steam generator tube rupture events.	2.02%	7.52%	$25,000	$1,500,000	Not Cost Effective	Elimination of all steam generator tube ruptures results in a benefit of $25,000 (analysis case SGTR). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,500,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CB-03	Increase the pressure capacity of the secondary side	Increase the secondary side pressure capacity enough that a steam generator tube rupture would not cause the relief valves to lift. This would prevent a direct release pathway to the environment following a steam generator tube rupture.	2.02%	7.52%	$25,000	>>$25,000	Not Cost Effective	Elimination of all steam generator tube ruptures results in a benefit of $25,000 (analysis case SGTR). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO IDENTIFYING OR COPING WITH CONTAINMENT BYPASS								
CB-04	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture	Enhance depressurization capabilities during steam generator tube rupture.	2.02%	7.52%	$25,000	$5,000,000	Not Cost Effective	Elimination of all steam generator tube ruptures results in a benefit of $25,000 (analysis case SGTR). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $5,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CB-07	Provide main steam safety valve and automatic depressurization valve scrubbing	Route the discharge from the main steam safety valves and automatic depressurization valves through a structure in which a water spray condenses the steam and removes most of the fission products. This enhancement would reduce the consequences of a steam generator tube rupture.	0%	100%	$178,000	$9,500,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $9,500,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CB-10	Direct steam generator flooding after a steam generator tube rupture, prior to core damage	Improve scrubbing of steam generator tube rupture releases by maintaining adequate water coverage of a ruptured steam generator tube.	2.02%	7.52%	$25,000	$35,000	Not Cost Effective	Elimination of all steam generator tube ruptures results in a benefit of $25,000 (analysis case SGTR). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO IDENTIFYING OR COPING WITH CONTAINMENT BYPASS								
CB-13	Install additional instrumentation for interfacing system LOCA sequences	Install pressure or leak monitoring instruments between the first two pressure isolation valves on low-pressure injection lines, residual heat removal suction lines, and high pressure injection lines to increase the ability to detect an interfacing system LOCA.	4.56%	35.87%	$86,000	$2,300,000	Not Cost Effective	Elimination of all core damage from ISLOCA results in a benefit of $86,000 (analysis case ISLOCA). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $2,300,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CB-14	Increase frequency of valve leak testing	Reduce the frequency of an interfacing system LOCA.	4.56%	35.87%	$86,000	>$86,000	Not Cost Effective	Elimination of all core damage from ISLOCA results in a benefit of $86,000 (analysis case ISLOCA). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CB-19	Ensure all interfacing system LOCA releases are scrubbed	Scrub interfacing system LOCA releases. One method would be to plug drains in the break area so the break point would be covered with water.	4.56%	35.87%	$86,000	>>$86,000	Not Cost Effective	Elimination of all core damage from ISLOCA results in a benefit of $86,000 (analysis case ISLOCA). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO IDENTIFYING OR COPING WITH CONTAINMENT BYPASS								
CB-20	Add redundant and diverse limit switch to each containment isolation valve	Enhance isolation valve position indication, reducing the frequency of containment isolation failure and interfacing system LOCAs.	4.56%	35.87%	$86,000	$1,000,000	Not Cost Effective	Elimination of all core damage from ISLOCA results in a benefit of $86,000 (analysis case ISLOCA). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
CB-23	Develop enhanced procedures for station blackout to prevent containment bypass	Add a procedural requirement to close manual valve 2HPA-2 to ensure that failure of 2SV-8231-2 will not introduce a small containment leak path.	0.02%	0.04%	$200	$35,000	Not Cost Effective	Elimination of all core damage attributable to plant damage state SBOu results in a benefit of $200 (analysis case CBPEN). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CB-26	Enhance plant procedures to improve credit for human action to prevent and cope with an interfacing system LOCA	Change plant operating procedures to isolate the low pressure safety injection line following the failure of series system check valves. Also, enhance operator training on coping with interfacing system LOCAs resulting from reactor coolant pump seal cooler tube ruptures.	3.36%	26.40%	$64,000	>$70,000	Not Cost Effective	Elimination of all human error associated with an interfacing system LOCA results in a benefit of $64,000 (analysis case ISLOCAHEP). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since several systems are impacted, this modification requires multiple procedure revisions. Implementation would also require increasing the inspection frequency for shutdown cooling suction line MOVs. As this SAMA requires multiple procedure modifications and in-service inspection costs, the cost of implementing this SAMA is >$70,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO CORE COOLING SYSTEMS								
CC-01	Provide capability for diesel-driven, low pressure vessel makeup	Provide an extra water source during sequences in which the reactor is depressurized and all other injection is unavailable (e.g., fire protection system).	100%	100%	$632,000	>$632,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
CC-02	Provide an additional high pressure injection pump with independent diesel	Reduce frequency of core melt from small LOCA sequences during station blackout events.	100%	100%	$632,000	$5,000,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $5,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO CORE COOLING SYSTEMS								
CC-07	Extend the reactor water storage tank source	Extend the reactor water storage tank capacity in the event of steam generator tube ruptures. Since the time available for recovery depends mostly on the refueling water storage tank inventory, the ability to refill the tank once it reaches a specified low level could prolong the cooling of the core for an indefinite period. Steam generator tube leak rate would need to be decreased (i.e., through primary system depressurization) to less than the available refueling water storage tank makeup capacity.	100%	100%	$632,000	$1,000,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
CC-14	Replace two of the four electric safety injection pumps with diesel-powered pumps	Reduce the probability of common cause failure of the safety injection system. This SAMA was originally intended for the Westinghouse-CE System 80+, which has four trains of safety injection. However, the intent of this SAMA is to provide diversity within the high- and low-pressure safety injection systems.	100%	100%	$632,000	$2,000,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $2,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO CORE COOLING SYSTEMS</u>								
CC-18	Modify the containment sump strainers to prevent plugging	Prevent plugging of the containment sump strainers by modifying the existing strainers and adding additional strainer area.	7.54%	0.88%	$36,000	>>$36,000	Not Cost Effective	Elimination of sump strainer plugging contribution to core damage results in a benefit of $36,000 (analysis case SUMPSTRAIN). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CC-19	Provide an additional flow path from the refueling water tank to the high-pressure safety injection system through a diversified suction flow path check valve	Reduce the potential for common cause failure of the refueling water tank flow path check valves.	5.45%	2.61%	$29,000	>>$29,000	Not Cost Effective	Elimination of all core damage due to failure of the high-pressure safety injection flow path check valves results in a benefit of $27,000 (analysis case HPSICV). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
CC-20	Make containment sump recirculation outlet valve motor-operated valves 2CV-5649-1 and 2CV-5650-2 diverse from one another	Replace either containment sump valve 2CV-5649-1 or 2CV-5650-2 with an air-operated valve. This would reduce the potential for common cause failure of these valves.	5.75%	2.75%	$31,000	>$31,000	Not Cost Effective	Elimination of all core damage due to containment sump valve failures results in a benefit of $31,000 (analysis case SUMPMOV). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO CORE COOLING SYSTEMS</u>								
CC-21	Provide actuator diversity for the motor-operated valves in the high-pressure safety injection system	Reduce the potential for common cause failure of high-pressure safety injection motor-operated valves by replacing redundant train valve actuators with diversified valve actuators.	4.06%	1.99%	$22,000	>$22,000	Not Cost Effective	Elimination of all core damage due to common cause failure of the high-pressure safety injection valves results in a benefit of $21,000 (analysis case HPSIMOV). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CC-22	Incorporate diversity among recirculation actuation signal and engineered safety features actuation signal actuation relays	Reduce the potential for common cause failure of two or more recirculation actuation signal and engineered safety features actuation signal actuation relays (e.g., K104A/B, SSR-1/3A, etc.) This modification would replace existing relays with relays of diverse design.	2.44%	2.01%	$15,000	>$15,000	Not Cost Effective	Elimination of all core damage due to common cause failure of engineered safety features actuation and solid state relays results in a benefit of $15,000 (analysis case ESFASRELAY). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
CC-23	Provide an additional recirculation actuation signal level transmitter (2LT-5636-5) and change recirculation actuation logic from 2-out-of-4 to 2-out-of-5	Increase the reliability of automatic recirculation swap-over. This modification would install an additional level transmitter and change the recirculation actuation logic from 2-out-of-4 to 2-out-of-5.	0.97%	0.09%	$5,000	>$5,000	Not Cost Effective	Elimination of all core damage due to failure of the recirculation actuation signal level transmitters results in a benefit of $5,000 (analysis case RASLEVEL). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO CORE COOLING SYSTEMS</u>								
CC-24	Provide bypass flow paths for all safety injection tanks	Provide a bypass flow path with a normally open motor-operated control valve around the safety injection tank discharge control valves. This modification would increase the probability of injection if the motor-operated control valves fail closed.	0.91%	0.15%	$4,000	>>$4,000	Not Cost Effective	Elimination of all core damage due to failure of safety injection tank discharge valves results in a benefit of $4,000 (analysis case SIMOV). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO LOSS OF COOLING WATER</u>								
CW-01	Cap downstream piping of normally closed component cooling water drain and vent valves	Reduce the frequency of loss of component cooling water initiating events, some of which are attributable to catastrophic failure of one of the m single isolation valves.	19.99%	11.94%	$112,000	>$112,000	Not Cost Effective	Elimination of all core damage due to loss of feedwater results in a benefit of $112,000 (analysis case FDW). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
CW-06	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heatup time	Increase time before reactor coolant pump seal failure during loss of service water sequences.	4.55%	2.74%	$25,000	$35,000	Not Cost Effective	Perfectly reliable recovery of service water results in a benefit of $25,000 (analysis case LOSWHEP). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO LOSS OF COOLING WATER								
CW-07	Increase charging pump lube oil capacity	This SAMA was intended to improve the reliability of seal cooling during normal operation via seal injection. Although ANO-2 does not use seal injection for seal cooling during normal operation, the charging pumps have a risk significant function to add boron to the RCS in the event of an ATWS.	1.95%	Not Estimated	$12,000	>>$12,000	Not Cost Effective	Making the charging pumps perfectly reliable results in a benefit of $12,000 (analysis case ATWS2). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CW-09	Provide an additional diversified service water pump	Decrease the frequency of core damage due to a loss of service water by installing an additional service water pump with an independent diesel generator. This modification also requires that one of the remaining service water pumps be supplied with an independent diesel to reduce the potential for common cause failure of all of the service water pumps.	32.16%	33.45%	$202,000	>$202,000	Not Cost Effective	Elimination of all core damage due to loss of service water results in a benefit of $202,000 (analysis case LOSW). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO LOSS OF COOLING WATER								
CW-10	Create an independent reactor coolant pump seal injection system, with dedicated diesel	Add redundant reactor coolant pump seal cooling, reducing the frequency of core damage from loss of component cooling water, service water, or station blackout. (Note: the Westinghouse-CE System 80+ includes a dedicated, positive displacement seal injection pump (air-cooled) independent of component cooling water.)	11.82%	10.71%	$71,000	>>$71,000	Not Cost Effective	Elimination of all seal LOCAs results in a benefit of $71,000 (analysis case SEALLOCA). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CW-11	Create an independent reactor coolant pump seal injection system, without dedicated diesel	Add redundant reactor coolant pump seal cooling, reducing the frequency of core damage from loss of component cooling water or service water, but not from a station blackout.	11.82%	10.71%	$71,000	>>$71,000	Not Cost Effective	Elimination of all seal LOCAs results in a benefit of $71,000 (analysis case SEALLOCA). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CW-13	Replace emergency core cooling system pump motors with air cooled motors	Eliminate emergency core cooling system dependence on service water.	32.16%	33.45%	$202,000	>$202,000	Not Cost Effective	Elimination of all core damage due to loss of service water results in a benefit of $202,000 (analysis case LOSW). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO LOSS OF COOLING WATER								
CW-14	Install improved reactor coolant pump seals	Reactor coolant pump seal O-rings constructed of improved materials would reduce the likelihood of reactor coolant pump seal LOCA.	11.82%	10.71%	$71,000	$2,500,000	Not Cost Effective	Elimination of all seal LOCAs results in a benefit of $71,000 (analysis case SEALLOCA). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $2,500,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CW-15	Install an additional component cooling water pump	Reduce the likelihood of loss of component cooling water leading to a reactor coolant pump seal LOCA.	12.71%	11.47%	$76,000	>>$76,000	Not Cost Effective	Elimination of all core damage due to loss of the component cooling water system results in a benefit of $76,000 (analysis case LOCCW). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CW-21	Implement procedure and operator training enhancements for support system failure sequences, with an emphasis on anticipating problems and coping	Improve the success rate of operator actions after support system failures.	4.55%	2.74%	$25,000	$35,000	Not Cost Effective	Perfectly reliable recovery of service water results in a benefit of $25,000 (analysis case LOSWHEP). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO LOSS OF COOLING WATER								
CW-22	Improve ability to cool residual heat removal heat exchangers	Reduce the chance of loss of decay heat removal by: (1) modifying procedures and hardware to allow manual alignment of the fire protection system to the component cooling water system; or (2) installing a component cooling water header cross-tie.	12.71%	11.47%	$76,000	$565,000	Not Cost Effective	Elimination of all core damage due to loss of the component cooling water system results in a benefit of $76,000 (analysis case LOCCW). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $565,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CW-23	Develop enhanced procedures for loss of service water	Enhance loss of service water procedures to improve the ability to avoid unnecessary low pressure safety injection and containment spray pump overheating failures that can minimize the benefit of restoring service water.	4.55%	2.74%	$25,000	$35,000	Not Cost Effective	Perfectly reliable recovery of service water results in a benefit of $25,000 (analysis case LOSWHEP). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
CW-24	Provide the ability to automatically trip the reactor coolant pumps on a loss of component cooling water	Reduce the potential for a seal LOCA following loss of component cooling water by reducing reliance on operator action to trip the reactor coolant pumps.	11.82%	10.71%	$71,000	>$71,000	Not Cost Effective	Elimination of all seal LOCAs results in a benefit of $71,000 (analysis case SEALLOCA). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO LOSS OF COOLING WATER								
CW-25	Add redundant control valve in series with 2CV-1530-1	Add a redundant valve in series with 2CV-1530-1 on service water header 1 (and 2CV-1531-2 on service water header 2). This SAMA would increase the reliability of isolation if the isolation valves supplying the component cooling water heat exchangers and main chillers fail to close upon demand.	1.62%	1.64%	$10,000	>$10,000	Not Cost Effective	Elimination of all core damage due to service water to CCW isolation valve failure results in a benefit of $10,000 (analysis case SWMOV). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
CW-26	Increase inspections of service water pump discharge filters	Reduce the failure frequency of the service water system. This SAMA would increase the inspection and cleaning frequency of the service water pump discharge filters, reducing the probability of a common cause failure.	16.17%	16.36%	$100,000	>$100,000	Not Cost Effective	Elimination of all common cause failures of service water pump discharge filters results in a benefit of $100,000 (analysis case FILTER). Currently, weekly cleaning of the service water strainer for one pump requires about six hours. Assuming $20/hour and bi-weekly cleaning for each strainer, the cost would be >$100,000 well before the end of the license renewal period. Therefore, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO LOSS OF COOLING WATER								
CW-27	Replace current service water pump discharge strainers with backwash filters	Reduce the failure frequency of the service water system. This SAMA would install backwash filters in place of the existing strainers, reducing the probability of a common cause failure.	16.17%	16.36%	$100,000	>$200,000	Not Cost Effective	Elimination of all common cause failures of service water pump discharge filters results in a benefit of $100,000 (analysis case FILTER). It was estimated that the material and installation of backwash filters for all three SW pumps would cost more than $79,000 (Reference E.2-6). With engineering, documentation and training, the total cost would be more than $200,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE								
EV-02	Install automatic containment spray pump header throttle valves	Extend the time during which water remains in the reactor water storage tank, when full containment spray flow is not needed.	0%	100%	$178,000	$375,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $375,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-04	Develop an enhanced drywell spray system	Provide a redundant source of water to the containment to control containment pressure. For a PWR, install a redundant containment spray system.	0%	100%	$178,000	$1,500,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,500,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE								
EV-05	Provide a dedicated drywell spray system	Similar to EV-04, except one of the existing spray loops would be used instead of developing a new spray system (i.e., new hardware, existing piping). In a PWR, develop a dedicated containment spray system.	0%	100%	$178,000	>>$178,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
EV-07	Install a filtered containment vent	Assuming injection is available (non-ATWS sequences), provide alternate decay heat removal and fission products scrubbing.	0%	100%	$178,000	$5,700,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $5,700,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
EV-08	Install an unfiltered containment vent	Provide an alternate decay heat removal method (non-ATWS) without fission product scrubbing.	0%	100%	$178,000	$3,100,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $3,100,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-09	Create/enhance hydrogen control system with independent power supply	Reduce hydrogen detonation using either a new, independent power supply; a non-safety grade portable generator; existing station batteries; or existing AC/DC independent power supplies, such as the security system diesel.	0%	100%	$178,000	$1,000,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE</u>								
EV-10	Create a passive hydrogen control system	Reduce hydrogen detonation potential without requiring electric power.	0%	100%	$178,000	$800,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $800,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-11	Create a refractory-lined crucible with heat removal potential under the basemat to contain molten debris	Provide a ceramic-lined concrete crucible and cooling system in the reactor cavity. A molten core escaping from the vessel would be contained within the crucible. Water cooling of the crucible would cool the molten core, preventing melt-through.	0%	100%	$178,000	$108,000,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $108,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
EV-12	Create a water cooled rubble bed on the pedestal	Provide a bed of refractory pebbles to impede the flow of molten corium to the concrete drywell structures and increase the available heat transfer area.	0%	100%	$178,000	$19,000,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $19,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE								
EV-15	Create a reactor cavity flooding system	Enhance the ability to cool debris, reduce core-concrete interaction, and provide fission product scrubbing.	1.48%	5.36%	$17,000	$8,750,000	Not Cost Effective	Elimination of core damage attributable to plant damage state IVKi results in a benefit of $17,000 (analysis case CAVITY). In 1999, the cost of implementing a similar SAMA at ANO-1 was estimated to be $8,750,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-16	Creating other options for reactor cavity flooding (Option 1)	Drill pathways in the reactor vessel support structure to allow drainage from the steam generator compartments, refueling canal, sumps, etc., to flood the reactor cavity. Also (for ice condensers), allow drainage of water from melted ice into the reactor cavity. This SAMA would enhance the ability to cool debris, reduce core-concrete interaction, and provide fission product scrubbing.	1.48%	5.36%	$17,000	>>$17,000	Not Cost Effective	Elimination of core damage attributable to plant damage state IVKi results in a benefit of $17,000 (analysis case CAVITY). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
EV-17	Creating other options for reactor cavity flooding (Option 2)	Flood the reactor cavity via systems like the diesel-driven fire pumps to enhance the ability to cool debris, reduce core concrete interaction, and provide fission product scrubbing.	1.48%	5.36%	$17,000	>>$17,000	Not Cost Effective	Elimination of core damage attributable to plant damage state IVKi results in a benefit of $17,000 (analysis case CAVITY). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE</u>								
EV-19	Provide a core debris control system	Prevent direct core debris attack of the primary containment steel shell by erecting a barrier to protect the containment walls from ejected core debris following a core melt scenario at high pressure.	0%	100%	$178,000	$45,000,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $45,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-21	Provide containment inerting capability	Prevent combustion of hydrogen and carbon monoxide gases.	0%	100%	$178,000	$10,900,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1999, the cost of implementing a similar SAMA at ANO-1 was estimated to be $10,900,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-22	Use fire water spray pump for containment spray	Provide a redundant containment spray method.	0%	100%	$178,000	$565,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $565,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
EV-23	Install a passive containment spray system	Provide containment spray with very high reliability and without support systems.	0%	100%	$178,000	>>$178,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE								
EV-25	Increase containment design pressure	Reduce the chance of containment overpressure.	0%	100%	$178,000	>>$178,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
EV-26	Provide an alternative concrete composition in the reactor cavity	Use an advanced concrete composition in the reactor cavity or increase the thickness of the concrete basemat to prevent basemat melt-through.	0%	100%	$178,000	$5,000,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $5,000,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
EV-27	Provide a reactor vessel exterior cooling system	Modify the reactor cavity configuration to externally cool the lower head of the reactor vessel following a core melt accident. This SAMA has the potential to cool a molten core before it causes vessel failure.	0%	100%	$178,000	$2,500,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $2,500,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
EV-28	Create a vacuum building	Provide a separate building maintained at vacuum to connect to the primary containment following an accident, thereby depressurizing the primary containment and further reducing emissions from severe accidents.	0%	100%	$178,000	>>$178,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
<u>ENHANCEMENTS RELATED TO EX-VESSEL ACCIDENT MITIGATION OR CONTAINMENT PERFORMANCE</u>								
EV-29	Add ribbing to the containment shell	Reduce the potential for buckling of the containment shell due to vacuum conditions (i.e., reverse pressure loadings).	0%	100%	$178,000	>>$178,000	Not Cost Effective	Elimination of all off-site releases results in a benefit of $178,000 (analysis case OFFSITE). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
EV-30	Provide actuator diversity for motor-operated valves in the containment spray system	Reduce the potential for common cause failure of containment spray system motor-operated valves by replacing redundant train motor-operated valve actuators with diverse valve actuators.	6.97%	3.81%	$38,000	>$38,000	Not Cost Effective	Elimination of all core damage due to common cause failure of containment spray valves results in a benefit of $38,000 (analysis case SPRAYMOV). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
EV-31	Remove reactor vessel cavity check valve 2BS-46 internals	Remove check valve internals to improve the potential for cooling communication between molten core debris in the bottom of the cavity and water on the containment floor. Improved cooling of a failed core would decrease the potential for a post severe accident off-site release.	1.48%	5.36%	$17,000	>$17,000	Not Cost Effective	Elimination of core damage attributable to plant damage state IVKi results in a benefit of $17,000 (analysis case CAVITY). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO FEEDWATER OR FEED AND BLEED RELIABILITY OR AVAILIABILITY								
FW-01	Install a digital feedwater upgrade	Reduce the likelihood of loss of main feedwater following a plant trip.	19.99%	11.94%	$112,000	>$112,000	Not Cost Effective	Elimination of all core damage due to loss of feedwater results in a benefit of $112,000 (analysis case FDW). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
FW-08	Provide hookup for portable generators	Temporary connections could allow portable generators to power the turbine-driven auxiliary feedwater pump controls after station batteries are depleted.	0.91%	0.29%	$5,000	>>$5,000	Not Cost Effective	Elimination of turbine-driven pump dependence on DC power results in a benefit of $5,000 (analysis case TDPUMPDC). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
FW-13	Install an independent diesel for the condensate storage tank makeup pumps	Allow continuous makeup to the condensate storage tank during a station blackout event.	17.79%	12.51%	$104,000	$271,000	Not Cost Effective	A perfectly reliable EFW system results in a benefit of $104,000 (analysis case EFW). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $271,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
FW-15	Create passive secondary side coolers	Provide a passive, secondary-side heat-rejection loop consisting of a condenser and heat sink to reduce the potential for core damage due to loss-of-feedwater events.	100%	100%	$632,000	>$632,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO FEEDWATER OR FEED AND BLEED RELIABILITY OR AVAILIABILITY								
FW-17	Enhance emergency feedwater flow control in the emergency operating procedures	Enhance emergency operating procedures to place emergency feedwater flow control valves in an open position once it has been determined that main steam isolation signal conditions do not exist. If the outboard flow control valves from both the motor-driven and turbine-driven were in a full open position upon loss of power supply, the potential for loss of flow to both steam generators would be minimized.	3.42%	0.75%	$17,000	$35,000	Not Cost Effective	Elimination of operator failure to open the emergency feedwater flow control valves results in a benefit of $17,000 (analysis case EFWCV). At ANO-2, the cost of modifying a plant procedure and the associated training is $35,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
FW-18	Replace current pilot operated relief valves with larger ones such that only one is required for successful feed and bleed	Remove potential for common cause failure of the pilot operated relief valves by replacing them with larger ones, such that only one is required.	100%	100%	$632,000	$2,700,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $2,700,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO FEEDWATER OR FEED AND BLEED RELIABILITY OR AVAILIABILITY								
FW-19	Create ability to automatically align emergency feedwater/auxiliary feedwater suction to the other condensate storage tank on low-low level of 2T-41A or 2T-41B	Create the ability to automatically align emergency feedwater/auxiliary feedwater suction to the other condensate storage tank on low-low level of 2T-41A or 2T-41B. This modification would reduce the potential for a loss of feedwater.	1.79%	1.29%	$10,000	>>$10,000	Not Cost Effective	Perfectly reliable re-alignment of EFW/AFW suction to the alternate condensate storage tank results in a benefit of $10,000 (analysis case CST). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO HEATING, VENTILATION AND AIR CONDITIONING								
HV-03	Develop enhanced procedures for temporary HVAC	Reduce probability of failure of HVAC recovery actions through the use of temporary equipment to cool both shutdown heat-exchanger rooms following a loss of two out of three room unit coolers in each room.	27.48%	29.73%	$174,000	>$300,000	Not Cost Beneficial	Perfectly reliable shutdown heat exchanger room cooling results in a benefit of $174,000 (analysis case HVAC). This SAMA requires a 60-ton, temporary industrial coolers for each of the shutdown heat exchanger rooms. The cooler should include a control system, an independent power source and a heat sink other than service water. The equipment must be maintained on-site and inspected/tested regularly for the duration of plant life. Operator training to stage the temporary coolers for appropriate use would also be required. One temporary cooling unit, diesel generator, control system and cooling water interface would cost over $150,000. As this SAMA requires two units, the minimum cost associated with implementation of this SAMA is >$300K. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
ENHANCEMENTS RELATED TO HEATING, VENTILATION AND AIR CONDITIONING								
HV-05	Create ability to switch fan power supply to station batteries in a station blackout	Allow continued fan operation in a station blackout. (This SAMA was created for a BWR reactor core isolation cooling room at the James A. Fitzpatrick Nuclear Power Plant. However, a similar SAMA may be applied to ANO-2's emergency feedwater room.)	17.79%	12.51%	$104,00	$226,000	Not Cost Effective	A perfectly reliable EFW system results in a benefit of $104,000 (analysis case EFW). In 1998, BG&E estimated the cost of implementing a similar SAMA at Calvert Cliffs to be $226,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
ENHANCEMENTS RELATED TO INSTRUMENT AIR								
IA-02	Replace current air compressors with more reliable models	Improve reliability and increase availability of instrument air compressors.	~0%	~0%	"minimal"	>>"minimal"	Not Cost Effective	Perfectly reliable air compressors result in minimal benefit (analysis case AIR). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.
OTHER ENHANCEMENTS								
OT-02	Create a reactor coolant depressurization system	Primary system depressurization would allow low pressure emergency core cooling system injection in the event of small LOCA and high-pressure safety injection failure. Even if core damage is not prevented, low primary system pressure alleviates some concerns about high pressure melt ejection. Modification could install a new depressurization system or utilize existing pilot-operated relief valves, head vents and secondary side valves.	100%	100%	$632,000	$4,600,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). In 1999, the cost of implementing a similar SAMA at ANO-1 was estimated to be $4,600,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.

Table E.2-1, Summary of SAMA Candidates Considered in Cost-Benefit Evaluation (continued)

SAMA ID	Potential Enhancement	Discussion	CDF Reduc-tion	Off-site Dose Reduction	Estimated Benefit	Estimated Cost	Conclusion	Basis for Conclusion
OT-06	Install secondary side guard pipes up to the main steam isolation valves	Prevent secondary side depressurization if a steam line break occurs upstream of the main steam isolation valves. This SAMA also prevents consequential multiple steam generator tube ruptures following a main steam line break event.	100%	100%	$632,000	$1,100,000	Not Cost Effective	Elimination of all core damage results in a benefit of $632,000 (analysis case MAXBENEFIT). In 1993, the cost of implementing a similar SAMA in the Westinghouse-CE System 80+ was estimated to be $1,100,000. Since the cost of implementing this SAMA exceeds the attainable benefit, this SAMA is not cost effective for ANO-2.
OT-07	Provide digital large break LOCA protection	Installation digital large break LOCA early detection instrumentation to improve the ability to identify precursors of a large break LOCA (i.e., a leak before break).	4.03%	3.49%	$24,000	>>$24,000	Not Cost Effective	Elimination of all core damage due to large LOCAs results in a benefit of $24,000 (analysis case LBLOCA). The cost of implementing this SAMA is judged to exceed the attainable benefit, even without a detailed cost estimate. Therefore, this SAMA is not cost effective for ANO-2.

Table E.2-2, Sensitivity Analysis Results

SAMA ID	Potential Enhancement	Estimated Benefit (baseline)	Estimated Cost	Estimated Benefit (Sensitivity 1)	Estimated Benefit (Sensitivity 2)	Estimated Benefit (Sensitivity 3)	Estimated Benefit (Sensitivity 4)	Estimated Benefit (Sensitivity 5)
AC/DC -02	Install a combustion turbine generator	$39,000	$3,350,000	$27,000	$42,000	$17,000	$39,000	$43,000
AC/DC -04	Use fuel cells in lieu of conventional lead-acid batteries	$34,000	$2,000,000	$23,000	$37,000	$15,000	$35,000	$38,000
AC/DC -05	Provide additional DC battery capability	$34,000	>$150,000	$23,000	$37,000	$15,000	$35,000	$38,000
AC/DC -06	Train operations crew for response to inadvertent actuation signals	$5,000	$35,000	$3,000	$5,000	$2,000	$5,000	$5,000
AC/DC -09	Improve bus cross-tie capability	$39,000	$1,119,000	$27,000	$42,000	$17,000	$39,000	$43,000
AC/DC -10	Incorporate alternate battery charging capabilities	$34,000	$134,000	$23,000	$37,000	$15,000	$35,000	$38,000
AC/DC -12	Replace current station batteries with a more reliable model	$34,000	>$150,000	$23,000	$37,000	$15,000	$35,000	$38,000
AC/DC -13	Create AC power cross tie capability across units at a multi-unit site	$39,000	>>$39,000	$27,000	$42,000	$17,000	$39,000	$43,000
AC/DC -15	Develop enhanced procedures to repair or change out failed 4KV breakers	$6,000	$35,000	$4,000	$6,000	$3,000	$6,000	$7,000
AC/DC -16	Emphasize steps in plant recovery following a station blackout event	$34,000	$35,000	$24,000	$37,000	$15,000	$34,000	$38,000
AC/DC -19	Create a back-up source for diesel cooling	$20,000	$1,700,000	$14,000	$22,000	$9,000	$20,000	$22,000
AC/DC -20	Use fire protection systems as a backup for diesel cooling	$39,000	>$497, 000	$27,000	$42,000	$17,000	$39,000	$43,000
AC/DC -21	Provide a connection to an alternate off-site power source	$39,000	>$25,000,000	$27,000	$42,000	$17,000	$39,000	$43,000
AC/DC -22	Implement underground off-site power lines	$39,000	>$25,000,000	$27,000	$42,000	$17,000	$39,000	$43,000

Table E.2-2, Sensitivity Analysis Result (continued)								
SAMA ID	**Potential Enhancement**	**Estimated Benefit (baseline)**	**Estimated Cost**	**Estimated Benefit (Sensitivity 1)**	**Estimated Benefit (Sensitivity 2)**	**Estimated Benefit (Sensitivity 3)**	**Estimated Benefit (Sensitivity 4)**	**Estimated Benefit (Sensitivity 5)**
AC/DC -24	Create the ability to automatically transfer battery charger/eliminator 2D31B to an alternate power source	$34,000	>>$34,000	$23,000	$37,000	$15,000	$35,000	$38,000
AT-01	Provide alternative ATWS pressure relief valves	$140,000	$1,000,000	$96,000	$151,000	$62,000	$140,000	$154,000
AT-02	Create a boron injection/shutdown system to backup the mechanical control rods	$140,000	$300,000	$96,000	$151,000	$62,000	$140,000	$154,000
AT-03	Provide a diverse plant protection system	$140,000	$3,000,000	$96,000	$151,000	$62,000	$140,000	$154,000
CB-01	Institute a maintenance practice to perform a 100% inspection of steam generator tubes during each refueling outage	$25,000	$1,500,000	$21,000	$29,000	$12,000	$25,000	$26,000
CB-03	Increase the pressure capacity of the secondary side	$25,000	>>$25,000	$21,000	$29,000	$12,000	$25,000	$26,000
CB-04	Install a redundant spray system to depressurize the primary system during a steam generator tube rupture	$25,000	$5,000,000	$21,000	$29,000	$12,000	$25,000	$26,000
CB-07	Provide main steam safety valve and automatic depressurization valve scrubbing	$178,000	$9,500,000	$178,000	$226,000	$91,000	$178,000	$178,000
CB-08	Provide additional steam generator tube rupture coping features	$25,000	>>$25,000	$21,000	$29,000	$12,000	$25,000	$26,000
CB-10	Direct steam generator flooding after a steam generator tube rupture, prior to core damage	$25,000	$35,000	$21,000	$29,000	$12,000	$25,000	$26,000
CB-13	Install additional instrumentation for interfacing system LOCA sequences	$86,000	$2,300,000	$78,000	$104,000	$42,000	$87,000	$90,000
CB-14	Increase frequency of valve leak testing	$86,000	>$86,000	$78,000	$104,000	$42,000	$87,000	$90,000
CB-19	Ensure all interfacing system LOCA releases are scrubbed	$86,000	>>$86,000	$78,000	$104,000	$42,000	$87,000	$90,000

SAMA ID	Potential Enhancement	Estimated Benefit (baseline)	Estimated Cost	Estimated Benefit (Sensitivity 1)	Estimated Benefit (Sensitivity 2)	Estimated Benefit (Sensitivity 3)	Estimated Benefit (Sensitivity 4)	Estimated Benefit (Sensitivity 5)
CB-20	Add redundant and diverse limit switch to each containment isolation valve	$86,000	$1,000,000	$78,000	$104,000	$42,000	$87,000	$90,000
CB-23	Develop enhanced procedures for station blackout to prevent containment bypass	$200	$35,000	$100	$200	$100	$200	$200
CB-26	Enhance plant procedures to improve credit for human action to prevent and cope with an interfacing system LOCA	$64,000	>$70,000	$57,000	$77,000	$31,000	$64,000	$66,000
CC-01	Provide capability for diesel-driven, low pressure vessel makeup	$632,000	>$632,000	$436,000	$686,000	$282,000	$638,000	$699,000
CC-02	Provide an additional high pressure injection pump with independent diesel		$5,000,000	$436,000	$686,000	$282,000	$638,000	$699,000
CC-07	Extend the reactor water storage tank source	$632,000	$1,000,000	$436,000	$686,000	$282,000	$638,000	$699,000
CC-14	Replace two of the four electric safety injection pumps with diesel-powered pumps	$632,000	$2,000,000	$436,000	$686,000	$282,000	$638,000	$699,000
CC-18	Modify the containment sump strainers to prevent plugging	$36,000	>>$36,000	$21,000	$37,000	$15,000	$36,000	$41,000
CC-19	Provide an additional flow path from the refueling water tank to the high-pressure safety injection system through a diversified suction flow path check valve	$29,000	>>$29,000	$19,000	$31,000	$13,000	$30,000	$33,000
CC-20	Make containment sump recirculation outlet valve motor-operated valves 2CV-5649-1 and 2CV-5650-2 diverse from one another	$31,000	>$31,000	$20,000	$33,000	$14,000	$32,000	$35,000
CC-21	Provide actuator diversity for the motor-operated valves in the high-pressure safety injection system	$22,000	>$22,000	$14,000	$23,000	$10,000	$22,000	$25,000

Table E.2-2, Sensitivity Analysis Result (continued)

SAMA ID	Potential Enhancement	Estimated Benefit (baseline)	Estimated Cost	Estimated Benefit (Sensitivity 1)	Estimated Benefit (Sensitivity 2)	Estimated Benefit (Sensitivity 3)	Estimated Benefit (Sensitivity 4)	Estimated Benefit (Sensitivity 5)
CC-22	Incorporate diversity among recirculation actuation signal and engineered safety features actuation signal actuation relays	$15,000	>$15,000	$10,000	$16,000	$7,000	$15,000	$17,000
CC-23	Provide an additional recirculation actuation signal level transmitter (2LT-5636-5) and change recirculation actuation logic from 2-out-of-4 to 2-out-of-5	$5,000	>$5,000	$3,000	$5,000	$2,000	$5,000	$5,000
CC-24	Provide bypass flow paths for all safety injection tanks	$4,000	>>$4,000	$3,000	$4,000	$2,000	$4,000	$5,000
CW-01	Cap downstream piping of normally closed component cooling water drain and vent valves	$112,000	>$112,000	$73,000	$119,000	$49,000	$113,000	$125,000
CW-06	On loss of essential raw cooling water, proceduralize shedding component cooling water loads to extend the component cooling water heatup time	$25,000	$35,000	$16,000	$27,000	$11,000	$26,000	$28,000
CW-07	Increase charging pump lube oil capacity	$12,000	>>$12,000	$9,000	$14,000	$6,000	$13,000	$14,000
CW-09	Provide an additional diversified service water pump	$202,000	>$202,000	$139,000	$219,000	$90,000	$204,000	$224,000
CW-10	Create an independent reactor coolant pump seal injection system, with dedicated diesel	$71,000	>>$71,000	$48,000	$76,000	$31,000	$72,000	$79,000
CW-11	Create an independent reactor coolant pump seal injection system, without dedicated diesel	$71,000	>>$71,000	$48,000	$76,000	$31,000	$72,000	$79,000
CW-13	Replace emergency core cooling system pump motors with air cooled motors	$202,000	>$202,000	$139,000	$219,000	$90,000	$204,000	$224,000
CW-14	Install improved reactor coolant pump seals	$71,000	$2,500,000	$48,000	$76,000	$31,000	$72,000	$79,000

Table E.2-2, Sensitivity Analysis Result (continued)

Table E.2-2, Sensitivity Analysis Result (continued)								
SAMA ID	**Potential Enhancement**	**Estimated Benefit (baseline)**	**Estimated Cost**	**Estimated Benefit (Sensitivity 1)**	**Estimated Benefit (Sensitivity 2)**	**Estimated Benefit (Sensitivity 3)**	**Estimated Benefit (Sensitivity 4)**	**Estimated Benefit (Sensitivity 5)**
CW-15	Install an additional component cooling water pump	$76,000	>>$76,000	$51,000	$82,000	$34,000	$77,000	$85,000
CW-21	Implement procedure and operator training enhancements for support system failure sequences, with an emphasis on anticipating problems and coping	$25,000	$35,000	$16,000	$27,000	$11,000	$26,000	$28,000
CW-22	Improve ability to cool residual heat removal heat exchangers	$76,000	$565,000	$51,000	$82,000	$34,000	$77,000	$85,000
CW-23	Develop enhanced procedures for loss of service water	$25,000	$35,000	$16,000	$27,000	$11,000	$26,000	$28,000
CW-24	Provide the ability to automatically trip the reactor coolant pumps on a loss of component cooling water	$71,000	>$71,000	$48,000	$76,000	$31,000	$72,000	$79,000
CW-25	Add redundant control valve in series with 2CV-1530-1	$10,000	>$10,000	$7,000	$11,000	$4,000	$10,000	$11,000
CW-26	Increase inspections of service water pump discharge filters	$100,000	>$100,000	$68,000	$108,000	$44,000	$101,000	$111,000
CW-27	Replace current service water pump discharge strainers with backwash filters	$100,000	>$200,000	$68,000	$108,000	$44,000	$101,000	$111,000
EV-02	Install automatic containment spray pump header throttle valves	$178,000	$375,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-04	Develop an enhanced drywell spray system	$178,000	$1,500,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-05	Provide a dedicated drywell spray system	$178,000	>>$178,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-07	Install a filtered containment vent	$178,000	$5,700,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-08	Install an unfiltered containment vent	$178,000	$3,100,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-09	Create/enhance hydrogen control system with independent power supply	$178,000	$1,000,000	$178,000	$226,000	$91,000	$178,000	$178,000

Table E.2-2, Sensitivity Analysis Result (continued)								
SAMA ID	**Potential Enhancement**	**Estimated Benefit (baseline)**	**Estimated Cost**	**Estimated Benefit (Sensitivity 1)**	**Estimated Benefit (Sensitivity 2)**	**Estimated Benefit (Sensitivity 3)**	**Estimated Benefit (Sensitivity 4)**	**Estimated Benefit (Sensitivity 5)**
EV-10	Create a passive hydrogen control system	$178,000	$800,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-11	Create a refractory-lined crucible with heat removal potential under the basemat to contain molten debris	$178,000	$108,000,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-12	Create a water cooled rubble bed on the pedestal	$178,000	$19,000,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-15	Create a reactor cavity flooding system	$17,000	$8,750,000	$14,000	$20,000	$8,000	$17,000	$18,000
EV-16	Creating other options for reactor cavity flooding (Option 1)	$17,000	>>$17,000	$14,000	$20,000	$8,000	$17,000	$18,000
EV-17	Creating other options for reactor cavity flooding (Option 2)	$17,000	>>$17,000	$14,000	$20,000	$8,000	$17,000	$18,000
EV-19	Provide a core debris control system	$178,000	$45,000,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-20	Create a core melt source reduction system (COMSORS)	$178,000	>>$178,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-21	Provide containment inerting capability	$178,000	$10,900,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-22	Use fire water spray pump for containment spray	$178,000	$565,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-23	Install a passive containment spray system	$178,000	>>$178,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-25	Increase containment design pressure	$178,000	>>$178,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-26	Provide an alternative concrete composition in the reactor cavity	$178,000	$5,000,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-27	Provide a reactor vessel exterior cooling system	$178,000	$2,500,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-28	Create a vacuum building	$178,000	>>$178,000	$178,000	$226,000	$91,000	$178,000	$178,000
EV-29	Add ribbing to the containment shell	$178,000	>>$178,000	$178,000	$226,000	$91,000	$178,000	$178,000

Table E.2-2, Sensitivity Analysis Result (continued)

SAMA ID	Potential Enhancement	Estimated Benefit (baseline)	Estimated Cost	Estimated Benefit (Sensitivity 1)	Estimated Benefit (Sensitivity 2)	Estimated Benefit (Sensitivity 3)	Estimated Benefit (Sensitivity 4)	Estimated Benefit (Sensitivity 5)
EV-30	Provide actuator diversity for motor-operated valves in the containment spray system	$38,000	>$38,000	$25,000	$40,000	$17,000	$38,000	$42,000
EV-31	Remove reactor vessel cavity check valve 2BS-46 internals	$17,000	>$17,000	$14,000	$20,000	$8,000	$17,000	$18,000
FW-01	Install a digital feedwater upgrade	$112,000	>$112,000	$73,000	$119,000	$49,000	$113,000	$125,000
FW-08	Provide hookup for portable generators	$5,000	>>$5,000	$3000	$5,000	$2,000	$5,000	$5,000
FW-13	Install an independent diesel for the condensate storage tank makeup pumps	$104,000	$271,000	$69,000	$111,000	$46,000	$105,000	$116,000
FW-15	Create passive secondary side coolers	$632,000	>$632,000	$436,000	$686,000	$282,000	$638,000	$699,000
FW-17	Enhance emergency feedwater flow control in the emergency operating procedures	$17,000	$35,000	$10,000	$17,000	$7,000	$17,000	$19,000
FW-18	Replace current pilot operated relief valves with larger ones such that only one is required for successful feed and bleed	$632,000	$2,700,000	$436,000	$686,000	$282,000	$638,000	$699,000
FW-19	Create ability to automatically align emergency feedwater/auxiliary feedwater suction to the other condensate storage tank on low-low level of 2T-41A or 2T-41B	$10,000	>>$10,000	$7,000	$11,000	$5,000	$11,000	$12,000
HV-03	Develop enhanced procedures for temporary HVAC	$174,000	>$300,000	$120,000	$189,000	$78,000	$176,000	$193,000
HV-05	Create ability to switch fan power supply to station batteries in a station blackout	$104,00	$226,000	$69,000	$111,000	$46,000	$105,000	$116,000
IA-02	Replace current air compressors with more reliable models	"minimal"	>>"minimal"	"minimal"	"minimal"	"minimal"	"minimal"	"minimal"
OT-02	Create a reactor coolant depressurization system	$632,000	$4,600,000	$436,000	$686,000	$282,000	$638,000	$699,000

Table E.2-2, Sensitivity Analysis Result (continued)

SAMA ID	Potential Enhancement	Estimated Benefit (baseline)	Estimated Cost	Estimated Benefit (Sensitivity 1)	Estimated Benefit (Sensitivity 2)	Estimated Benefit (Sensitivity 3)	Estimated Benefit (Sensitivity 4)	Estimated Benefit (Sensitivity 5)
OT-06	Install secondary side guard pipes up to the main steam isolation valves	$632,000	$1,100,000	$436,000	$686,000	$282,000	$638,000	$699,000
OT-07	Provide digital large break LOCA protection	$24,000	>>$24,000	$16,000	$26,000	$11,000	$25,000	$27,000