

19R Probabilistic Flooding Analysis

The information in this section of the reference ABWR DCD, including all subsections, tables, and figures, is incorporated by reference with the following departures and supplements.

STP DEP 1.2-2

STP DEP T1 5.0-1

STP DEP 9.2-10 (Table 19R-1)

STP DEP 19R-1 (Table 19R-7)

STP DEP 10.4-2

19R.1 Introduction and Summary

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

The ABWR has been designed to withstand the effects of postulated flooding internal to the plant. This appendix discusses the capabilities of the ABWR to withstand internal flooding (e.g., service water, suppression pool line breaks).

Results of the ABWR probabilistic flood analysis show:

- (1) *The only buildings where potential flooding could damage safety-related equipment or cause plant transients are the turbine, control, service and reactor buildings, and the Reactor Service Water (RSW) pump house. The radwaste building does not contain safety-related equipment and flooding cannot affect safety-related equipment in other buildings. Failure of seals in the radwaste tunnels between buildings was determined to result in several orders of magnitude lower core damage frequency than direct flooding due to pipe breaks in each building and was not included in the flooding event trees.*
- (2) *The flood concern for the turbine building is water filling up the condenser pit and flowing into the service building tunnel which is the access path to the reactor and control buildings. The reactor and control buildings contain safe shutdown equipment. The turbine building has the potential to be flooded by two unlimited sources: circulating water and turbine service water. The condenser pit contains redundant water level sensors (in a two-out-of-four logic) which send an alarm to alert the operator to potential flooding and automatically trip the circulating water system (CWS) pumps and close CWS isolation valves. In the unlikely event this automatic protection fails and the operator fails to take any action, potential flood waters would still be prevented from reaching the service building. Potential flood waters would be expected to exit the turbine building through the non-watertight truck entrance door. Also, there is a normally closed and alarmed door separating the turbine and service building access tunnel. If this door were to open due*

to water pressure from the flood, watertight doors at the entrances to the reactor and control buildings from the service building should prevent damage to safety-related equipment. Turbine service water (TSW) breaks must be manually mitigated by either tripping the pumps, or closing valves, or opening the truck entrance door. Sufficient time is available to complete these actions (greater than several hours) due to the relatively low TSW flow and the large size of the turbine building. CWS breaks dominate the CDF so no TSW event trees were completed. Thus, no impact on plant safety is expected from potential turbine building flooding. The estimated core damage frequency from turbine building flooding is extremely small for a plant with a low power cycle heat sink (PCHS) and is slightly higher for a high PCHS.

- (3) ~~The reactor building service water (RSW) system~~ The control building could potentially be flooded by the ~~reactor building service water (RSW)~~ system which is an unlimited source or by breaks in the Fire Water System. The control building has six floors but floor drains and stairwells would direct all potential flood waters to the bottom floor where the safety-related reactor building cooling water (RCW) system components are located. There are three divisions of RCW/RSW in physically separate rooms with watertight doors.

The RCW/RSW rooms in the control building lower level contain two sets of water level sensors in each division in a two-out-of-four logic. The first set of sensors send an alarm signal to the operator at 0.4 meter. The second set of sensors are actuated at 1.5 meters and send an alarm signal to the operator and trip the RSW pumps and close RSW system isolation valves in the affected division. Water remaining in the lines between the control building and the ultimate heat sink could be ~~siphoned or drained~~ into the control building. The water pumped into the control building prior to isolation of the RSW system and the water drained in from the RSW line outside is limited to affecting only one RCW division. The two other safety divisions (or alternate means) would remain undamaged and able to be used to achieve safe shutdown if necessary. The estimated core damage frequency from RSW flooding is extremely small.

Fire Water System breaks could cause flooding in all three safety divisions on a given floor since doors separating the divisions do not have sills. Floor drains and other floor openings in all three divisions ensure that postulated fire water breaks, if unisolated, will be directed to the first floor. The CDF for fire water flooding in the Control Building is extremely small.

The total control building flooding CDF is extremely small.

- (4) The reactor building is adequately protected from flooding concerns by the following:

- (5) The RSW pump house could also be potentially flooded by breaks in the RSW system, which is an unlimited source of water from the Ultimate Heat Sink (UHS). The RSW pump house has two floors, the pump room floor at elevation (-) 18 ft, and the electrical and HVAC room at elevation 14 ft, and is divided into three physically separate sections, by 3 hour fire-rated concrete walls and 3 hour fire-rated watertight doors between the pump rooms and between the electrical and HVAC rooms. The watertight doors provide emergency and maintenance access to the rooms on each level. The watertight doors are capable of withstanding full flood pressure in either direction, and are alarmed at a security alarm station if open, and in the Control Room if not dogged closed.

The roof of the RSW pump house is at elevation 50 ft, which is above the site Design Basis Flood level. There are no openings into the RSW pump house below 50 ft. The entrance to the RSW pump house is from the roof.

Within each RSW pump rooms, two lines from the UHS, at approximately 8 ft elevation, supply water to the two, horizontal RSW pumps in each division through a normally open, locked open, manual valve. After the RSW pump, the associated RSW strainer, and the pump discharge isolation motor operated valve (MOV), the RSW supply lines combine into a single supply line per division with a division isolation MOV. RSW then passes into the divisionally separated RSW tunnel to supply the RSW/RCW heat exchangers in the basement of the Control Building. Return from the RSW/RCW heat exchangers enters the associated divisionally separated RSW tunnel, enters and passes through the RSW pump room, the return isolation MOV, and discharges to the UHS basin above the UHS operating water level.

The RSW supply line to each RSW pump is designed in accordance with break exclusion criteria, which eliminates pipe stress as a potential failure mechanism. In addition, UHS water is treated to minimize the effects of corrosion and fouling and the reinforced concrete wall common to the UHS basin and RSW pump house is designed with reduced allowable stresses to minimize the potential for concrete cracking.

Two sets of water level sensors in each division pump room are arranged in a two-out-of-four logic. The first set of sensors end an alarm signal to the operator at 0.4 meter. The second set of sensors are actuated at 1.5 meters and send an alarm signal to the operator and trip the RSW pumps and close the RSW motor operated isolation valves in the affected division. The RSW line before the automatic isolation valve in the pump discharge is isolable with operator action to unlock and close the normally open, locked open manual suction isolation valve.

With an unisolable break in a RSW line, the pump room will flood, the electrical and HVAC room above the pump room will flood, and water will exit the RSW pump house through HVAC ventilation intake and discharge penetrations in the roof of the RSW pump house (one set for each division)

disabling the associated RCW and essential core cooling system division. The other two safety division (or alternate means) would remain undamaged and able to be used to achieve safe shutdown. The estimated core damage frequency from RSW pump house flooding is extremely small.

Fire Water System breaks could cause flooding in a single RSW division, but the division separation described above serves to limit the effects of Fire Water System breaks to that RSW division. The expected flood effects from fire water system breaks in a single RSW division are not expected to be as severe as the RSW piping breaks analyzed because the flow rates are significantly less allowing more time for operator action to stop or reduce the flow. The core damage frequency for fire water flooding in the RSW pump house is extremely small.

The total RSW pump house flooding core damage frequency is extremely small.

- (6) ~~(4) The total RSW pump house flooding core damage frequency is extremely small.~~ The estimated total core damage frequency from internal flooding is very small for a high PCHS. This low risk level is attributable to the relatively low probability of large internal floods and the physical separation of certain safety equipment in the ABWR design. It is highly unlikely that a single flood can result in loss of more than one safety division. Where there is a potential for large flood sources to affect equipment in more than one division, instrumentation for detecting the flood and isolating the flood source is provided. The two remaining safety divisions and alternate core cooling and decay heat removal features (e.g., AC independent water addition, power conversion system) give high assurance of achieving safe shut down.

19R.3 Screening Analysis (Water Sources and Buildings)

In order to focus the flooding analysis on buildings and water sources that have the potential to cause flooding concerns, a screening analysis was completed to eliminate sources and buildings that, for various reasons, do not require further analysis.

The screening analysis was carried out for each of the buildings. From a safe shutdown perspective, the radwaste building does not contain any equipment that is required for safe shutdown and because of physical separation, flooding cannot affect safe shutdown equipment in other buildings. Therefore, the radwaste building was not evaluated further for flooding concerns. Failure of seals in the radwaste tunnels between buildings was determined to result in several orders of magnitude lower core damage frequency than direct flooding due to pipe breaks in the buildings and was not included in the flooding event trees. Adequacy of these seals should be confirmed by the COL applicant. The turbine building does not contain any safe shutdown equipment but a flood could cause a turbine trip which is an accident initiator. Also, the turbine building is next to the service building which is the access to the reactor and control buildings and so flooding between the two buildings must be considered. The reactor and the control buildings, and the RSW pump house contain safe shutdown equipment (e.g., RHR, RCIC, HPCF, RSW, Class 1E batteries). The flooding analysis

will thus focus on the turbine, control, service and reactor buildings, and the RSW pump house, all of which either contain safety-related equipment or where flood damage could result in plant transients.

19R.4 Deterministic Flood Analysis

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

This subsection summarizes the physical design features of the ABWR that are capable of mitigating the effects of potential floods. A more detailed discussion of ABWR flooding features is contained in Tier 2 Subsection 3.4. The analysis will focus on the turbine, control, and reactor buildings, and the RSW pump house.

19R.4.2.4 Watertight Doors

STP DEP T1 5.0-1

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

ECCS equipment rooms on the first floor of the reactor and control buildings, the RSW pump rooms, and the RSW electrical and HVAC rooms have watertight doors. Also, external entrances to the control and reactor buildings below flood level (Refer to Section 3.4) have watertight doors. The external entrance to the RSW pump house is above the design basis flood level. The entrance to other divisional rooms have fire rated doors. These doors are normally closed and are included in the security surveillance system. These doors can be opened only with a card key and if left open security personnel will be alerted immediately. This system gives high assurance that the divisional separation will not be breached due to a door being inadvertently left open. The alarm system can detect if a watertight door is closed but not if it is dogged. The watertight doors in the RSW pump house are alarmed in the Control Room if the door is not dogged. A once per shift walkdown will ensure that watertight doors remain dogged when not in use.

19R.4.2.5 Floor Drains

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

The reactor and control buildings, and the RSW pump house contain floor drains to direct potential flood waters to rooms where sumps and sump pumps are located. The drain system is sized to withstand breaks in the fire water system which is the most probable flood source for these two buildings. Sizing of the drain system will include provisions for plugging of some drains by debris.

19R.4.3 Turbine Building Features

STP DEP 1.2-2

~~There is no safety-related equipment located in the turbine building. It is included as part of the detailed flood analysis because it contains non-safety-related equipment (e.g., condenser, condensate pumps) that could be used to achieve safe shutdown if required, a turbine building flood could result in a turbine trip which is a transient initiator, and because it is connected to the control and reactor buildings through the service buildings access tunnel. Since the control and reactor buildings contain safety-related equipment, interbuilding flooding must be addressed.~~

STP DEP 10.4-2

~~If either the circulating or turbine service water systems were to develop a leak and flood the turbine building, several features exist to mitigate the consequences of the flood. There are four circulating water pumps and three turbine service water pumps with three four circulating water pumps and two turbine service water pumps in operation supplying water from the intake structure to the screenhouse to the turbine building. Each pump has an associated motor operated isolation valve with the isolation valve on any idle circulating water pump closed. The condenser pit has redundant water level sensors arranged in a two-out-of-four logic. If flooding were to occur, the level sensors would alert the control room operator, trip the CWS pumps and close CWS valves. For breaks in the TSW system, adequate time (greater than 2 hours) is available for operator action to trip pumps, or close isolation valves, or open the truck entrance door.~~

19R.4.4 Control Building

STP DEP 19R-1

~~The RCW/RSW rooms contain two sets of diverse safety grade level sensors in a two out of four logic. The first set is located at 0.4 meters from the floor and is intended to alert the control room operator to investigate for the presence of water in the RCW/RSW rooms. The second set of sensors are located at 1.5 meters and informs the control room operators that a serious condition exists that needs immediate attention. In addition, the upper level sensors trip the RSW pumps and close redundant supply side motor operated isolation valves in the RSW system of the affected division. Redundant motor-operated valving is provided to ensure that the UHS basin water does not gravity drain to the control building.~~

~~Anti siphon capability (e.g., vacuum breakers, air breaks) is included to prevent continued flooding in the event that the RSW pump is tripped but the isolation valves do not close. Figure 19R-2 depicts the RSW system. Given that the pumps have tripped, actuation of the anti siphon redundant automatic isolation capability will terminate the flood. The ABWR UHS cannot gravity drain into the control building.~~

~~From the above, it is concluded that the only flooding concern in the control building is a leak in the RSW system that threatens the RCW system motors in the RCW/RSW rooms. If the upper level sensor alarms, it is a clear indication of a major RSW system leak in the RCW/RSW room.~~

~~The following assumptions are used in this “worst case” control building flood:~~

- ~~(1) The ultimate heat sink (UHS) is at an elevation higher than the control building RCW/RSW rooms such that siphoning draining of UHS water through the RSW system to the RCW/RSW rooms is possible.~~
- ~~(2) There is a maximum of 4000 meters of pipe (2000 each for supply and return) between the UHS and the RCW/RSW room which can be discharged to the RCW/RSW room following RSW pump trip.~~
- ~~(2) (3) The size of the RSW crack is about 103 cm² (16 in²) per ANSI/ANS 58.2 and BTP-MEB 3-1.~~
- ~~(3) (4) The leak occurs in the RCW/RSW room.~~
- ~~(4) (5) No operator action was assumed.~~

~~The results of this “worst case” control building flood are:~~

- ~~(1) A leak occurs in the RCW/RSW room with the RSW pump running and the lower level sensor alarms at 0.4 meters.~~
- ~~(2) The water level continues to rise and reaches the high level sensor. The RSW pumps in the leaking division are tripped at 1.5 meters.~~
- ~~(3) Water flows into the RCW/RSW room from the 4000 meters of RSW pipe-piping outside the control building.~~
- ~~(4) No water leaves the flooded room and only one division of RCW is affected.~~

~~The RCW/RSW rooms contain two sets of diverse safety grade level sensors in a two-out-of-four logic. The first set is located at 0.4 meters from the floor and is intended to alert the control room operator to investigate for the presence of water in the RCW/RSW rooms. The second set of sensors are located at 1.5 meters and informs the control room operators that a serious condition exists that needs immediate attention. In addition, the upper level sensors trip the RSW pumps and close redundant supply side motor operated isolation valves in the RSW system of the affected division.~~

~~Redundant motor operated valving is provided to ensure that the UHS basin water does not gravity drain to the control building.~~

~~From the above, it is concluded that the only flooding concern in the control building is a leak in the RSW system that threatens the RCW system motors in the RCW/RSW rooms. If the upper level sensor alarms, it is a clear indication of a major RSW system leak in the RCW/RSW room. The following assumptions are used in this “worst case” control building flood:~~

The following assumptions are used in this “worst case” control building flood:

- (1) ~~(5)~~ The ultimate heat sink (UHS) is at an elevation higher than the control building RCW/RSW rooms such ~~that that~~ draining/siphoning of UHS water through the RSW system to the RCW/RSW rooms is possible.
- (2) ~~(6)~~ There is ~~a maximum~~ approximately of 580 ~~4000~~ meters of pipe (270 m ~~2000~~ ~~each~~ for supply and 310 m return) between the UHS and RCW/RSW room which can be discharged to RCW/RSW room following RSW pump trip.
- (3) ~~(7)~~ The size of the RSW crack is about 103 cm² (16 in²) per ANSI/ANS-58.2 and BTP MEB 3-1.
- (4) ~~(8)~~ The leak occurs in the RCW/RSW room.
- (5) ~~(9)~~ No operator action was assumed.

The results of this “worst case” control building flood are:

- (1) A leak occurs in the RCW/RSW room with the RSW pump running and the lower level sensor alarms at 0.4 meters.
- (2) The water level continues to rise and reaches the high level sensor. The RSW pumps in the leaking division are tripped and redundant supply isolation valves are automatically isolated at 1.5 meters.
- (3) Water flows into the RCW/RSW room from the ~~4000~~ 580 meters of RSW pipe outside the control building.
- (4) No water leaves the flooded room and only one division of RCW is affected.

19R.4.6 RSW Pump House

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

The RSW pump house contains the safety-related RSW pumps and support equipment that could be used to achieve safe shutdown. Potential flooding of the RSW pump house could thus negatively impact the plant’s ability to reach and maintain safe shutdown.

Of the two sources of water in the RSW pump house listed in Table 19R-1, the fire water system flowrate is low and the system contains a flow alarm to alert the operator to a potential flooding condition. Adequate time would be available to locate and isolate fire water system leaks before any safety-related equipment would be damaged.

The only flooding concern in the RSW pump house are potential leaks in the RSW system from the UHS, which is an unlimited source. Leaks in the RSW piping could cause flooding damage to the RSW pumps in the bottom floor and, if unisolated, the electrical and HVAC equipment in the floor above. The three RSW divisions are

physically separated into watertight compartments to the roof level. Each room is equipped with a sump pump.

Two sets of water level sensors in each division pump room are arranged in a two-out-of-four logic. The first set of sensors send an alarm signal to the operator at 0.4 meter. The second set of sensors are actuated at 1.5 meters and send an alarm signal to the operator and trip the RSW pumps and close the RSW motor-operated isolation valves in the affected division. The RSW line before the automatic isolation valve in the pump discharge is isolable with operator action to unlock and close the normally open, locked open manual suction isolation valve.

From the above, it is concluded that the only flooding concern in the RSW pump house is an unisolable leak in the RSW piping that threatens the RSW motors and associated support equipment. If the upper level sensor alarms, it is a clear indication of a major RSW system leak in the RSW pump house.

The following assumptions are used in this “worst case” RSW pump house flood:

- (1) The size of the RSW crack is approximately 103 cm² (16 in²) per ANSI/ANS-58.2 and BTP MEB 3-1.
- (2) The leak occurs in the RSW pump room.
- (3) No operator action was assumed.

The results of this “worst case” RSW pump house flood are:

- (1) A leak occurs in the RSW pump room and the lower level sensor alarms at 0.4 meters.
- (2) The water level continues to rise and reaches the high level sensor. The RSW pumps in the leaking division are tripped at 1.5 meters.
- (3) Water flows into the RSW room from the UHS.
- (4) No water leaves the flooded division until it exits the HVAC supply and return at the roof of the RSW pump house. Only a single division of RSW and ECCS is affected.

From the above, it is concluded that there are no flooding concerns in the RSW pump house because most sources of water are either not large enough or leak at small enough rates that no equipment damage could reasonably occur. The only potential water source of concern is the RSW system and only one division of RSW would be affected. The reactor could be brought to safe shutdown using equipment from the other two divisions.

19R.5.2 Methodology

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

- (5) For the RSW pump house flood evaluation, the data developed to quantify the Control Building flooding is used to perform a similar bounding evaluation of the consequences of flooding in the RSW pump house.

19R.5.3 Turbine Building

STP DEP 1.2-2

The turbine building does not contain any safety-related equipment with the exception of instrumentation associated with Reactor Protection System and condensate pump motor trip circuit breakers. ~~But~~ Although the instrumentation and the circuit breakers are located at or above elevation 19700 TMSL (59'-3 1/2" MSL) well above the internal flood level described below and the external flood level of 40.0 ft MSL and prevented from the floods, the flooding of the turbine building can initiate a reactor trip and may impact the safe shutdown of the plant if the water reaches the control building through the service building access tunnel. There are several water sources listed in Table 19R-1 that may leak into the turbine building. Only the two unlimited water sources (circulating water and turbine service water) are capable of flooding the turbine building and threatening safety equipment in the control building.

STP DEP 10.4-2

The following site-specific supplement addresses the STP Site being a high PCHS design and having all openings to safety-related buildings below flood level closed.

The circulating water system (CWS) has ~~three~~ four pumps located in the main intake structure and each pump has an associated motor operated isolation (shutoff) valve. All of the four pumps are normally operating. The turbine service water (TSW) system has three pumps and three motor operated isolation valves. For a ~~the high power cycle heat sink~~ PCHS plant design at STP 3 & 4 (i.e., the heat sink is at an elevation higher than grade level of the turbine building), an additional isolation valve is installed in each line. All of these are classified as non-safety grade equipment. If a large pipe break develops either in the CWS or TSW piping and initiates flooding in the turbine building, it is necessary ~~either to trip all of the pumps (for a low heat sink) or to close all of the valves of the associated system to terminate the flood.~~ Four redundant ~~safety grade~~ water level sensors (operating in a two-out-of-four logic) in the condenser pit of the turbine building will generate a signal to alert the control room operator and trip all pumps and close all isolation valves in the CWS. TSW breaks must be manually mitigated but, due to the lower flow rate (Compared to CWS), sufficient time is available to trip the pumps or close isolation valves from the control room. A turbine trip and reactor shutdown will be initiated as a consequence of turbine building flooding.

If one or more pumps fail to trip or its associated valves ~~fails~~ fail to close, the water level may rise up to the top of the condenser pit and reach grade level. If the operator received an alarm from the level sensors, even though the automatic protective features failed, the operator could open the truck entrance door (roll up type door) to allow the flood water to exit the building. If the operator does not receive an alarm, it is assumed that insufficient time will be available for the operator to open the truck door

for a CWS break before the water level would effectively cause binding of the door and prevent opening. For TSW breaks, greater than 2 hours is available to open the door.

If the service building door fails open, the flood rate into the service building could be high enough to flood the service building to a significant level. Since the service building is the main entrance to the plant, personnel would hear or see the flood water and alert operators in the control room. Operator action could then be taken to manually ~~trip the CWS or TSW pumps or~~ close CWS or TSW valves. This is assuming that the level sensors failed but control circuitry for ~~pump trip/~~ valve isolation was still available.

If these actions failed, the flood waters would fill up the service building and could potentially enter the control or reactor buildings through several external normally closed watertight doors. On the first floor of the service building there is a watertight door which allows entrance to the reactor building cooling water (RCW) heat exchanger rooms. Failure of this door could allow the flood waters to damage equipment in all three safety divisions and potentially the battery room on the next level. If the watertight door to the RCW rooms does not fail, the water level would rise up in the service building to the next level where there are two watertight doors, one to the battery rooms of the control building and another to the reactor building clean access area. Failure of the watertight door to the battery rooms is assumed to result in core damage as loss of all DC (batteries and battery chargers) will occur. DC power is required for control of safe shutdown systems or to depressurize and use non-safety-related makeup sources such as condensate or AC independent water addition systems. Failure of the watertight door to the reactor building clean access area could result in damage to all three electrical divisions. If none of these watertight doors fail, flooding could continue to the next level where a ~~normally open~~ watertight door, normally closed except for routine ingress and egress, allows access to the control room area. Given the extensive flooding which had occurred to this point, the operators would have sufficient time and warning to ensure that ~~else~~ this watertight door is closed. If the door failed or the operators failed to close it, no core damage should occur because automatic initiation of safety systems such as the high pressure core flooders would ensure that the core remained covered with water. Continued flooding would then reach grade level where the water could exit the service building through the main entrance. It is assumed that failure of any of the external watertight doors (except the control room door) results in core damage.

Figures 19R-7 and 19R-8 are event trees which describe the turbine building flooding for low and high Power Cycle Heat Sink (PCHS) configurations, respectively. Note that Figure 19R-7 does not apply to STP 3 & 4 because they are a high PCHS design as described in Section 2.4S.1.1. The accident progression due to a large pipe break in the CWS (the worst case flooding) is described in the event tree. As the CWS break is bounding, no TSW flooding event trees were developed. The success or failure of each flood mitigating feature in the event tree diagram may have a significant impact on the result of accident progression. The event trees in Figures 19R-7 and 19R-8 are described as follows:

- (2) ~~Four redundant safety-grade water level sensors (operating in two-out-of-four-logic) in the condenser pit of the turbine building detect and alert control room operators about flooding (detection).~~
- (3) ~~The bus breaker and/or pump breakers of CWS pumps open and trip all three operating pumps (flooding prevention for low PCHS). Although siphoning could occur if the PCHS was higher than the bottom of the condenser pit, the siphon could not cause flooding to grade level. Therefore, the flood would be contained within the turbine building. In case of the high PCHS design of STP 3 & 4, the success probability of this feature is not credited for turbine building flood mitigation assumed to be zero.~~
- (4) ~~CWS isolation valves close (flooding prevention for high or low PCHS).~~
- (8) ~~The control room operator can prevent flood damage to safety-related equipment by manually tripping the CWS pumps or closing the CWS valves. It is assumed that if automatic features failed (given that the sensors did not fail) that control room actuations would also fail. If the sensors failed though, it may be possible to manually close the valves or trip the pumps from the control room once the operator is aware of the flooding condition. The probability of success is higher if the sensors did not fail because the operator would receive two indications of flooding: early in the scenario from the sensors in the turbine building and later from personnel in the service building if the flood were to propagate to that point. In either case, the watertight doors in the control and reactor buildings can prevent damage to safety-related equipment.~~

~~The description of flooding for a high PCHS is the same as for a low PCHS except that the pump tripping feature is not credited.~~

The core damage frequency for turbine building flooding is extremely small for a low PCHS and slightly higher for a high PCHS design of STP 3 & 4.

19R.5.4.1 RSW Line Breaks

STP DEP 19R-1

The RSW system is the only unlimited water source that could cause substantial flooding in the control building (Table 19R-1). It is highly unlikely that RSW flooding could damage more than one safety division. But the occurrence of several unlikely random failures and operator errors could result in flooding damage to equipment in all three RCW divisions.

The safety-related RCW motors are located on the -8,200 mm elevation (the lowest level of the control building) in three RSW/RCW rooms which are physically separated from each other by concrete walls and watertight doors. Each RSW/RCW room is also equipped with a sump pump.

Each of the three RSW divisions has two safety grade pumps and safety grade motor operated isolation (shutoff) valves, ~~and anti-siphon capability (e.g., vacuum breaker)~~ (Figure 19R-2). During normal operation, one pump in each ~~division~~ division is operating and the other pump is in standby. If a large leak or a pipe break develops in any one of the RSW/RCW rooms, tripping the pump and closing the associated valves in the affected division will stop the flooding. If the RSW pump trips ~~and but one~~ isolation valves fails to close, then the redundant set of isolation valves anti-siphon capability prevent continued flooding. Four redundant safety grade water level sensors (operating in a two-out-of-four logic) at the lower level (0.4 meter) of the control building will generate a signal to alert the control room operator. If the control room operator fails to take appropriate action to stop the water flow, the second set of level sensors will actuate when the water reaches the 1.5 meter level of the room. At this level, the sensors (operating in two-out-of-four logic) not only send an alarm signal to the operator but also trip the affected RSW pump and close all the isolation valves. The upper level sensors are diverse from the lowest level sensors.

19R.5.6 RSW Pump House

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

The RSW pump house contains the safety-related RSW system, which is used to remove the heat from the RCW heat exchangers. The RSW pump house could potentially be flooded by the RSW system which is an unlimited water source. Unisolated breaks in the fire water system could cause inter-divisional flooding since the RSW divisional separation splits the RSW pump house into three, watertight compartments. Watertight doors separate the RSW divisions.

19R.5.6.1 RSW Line Breaks

The UHS is an unlimited water source that could cause substantial flooding in the RSW pump house (Table 19R-1). It is highly unlikely that RSW flooding could damage more than one safety division. But the occurrence of several unlikely random failures and operator errors could result in flooding damage to equipment in all three RSW divisions.

The safety-related RSW pump motors are located on the lowest level of the RSW pump house in three RSW pump rooms which are physically separated from each other by concrete walls and watertight doors. Each RSW pump room is also equipped with a sump pump.

Each of the three RSW divisions has two safety grade pumps, safety grade discharge MOVs, a common header supply and return MOV and manually operated, normally open and locked open pump suction isolation valves. During normal operation, one pump in each division is operating and the other pump is in standby. If a large leak or a pipe break develops in any one of the RSW rooms, tripping the pump and closing the associated MOVs in the affected division will stop the flooding if it is downstream of the pump discharge MOV or in the RSW return line to the UHS. If the break is upstream of

the RSW discharge MOV, the break is unisolable without operator action to close the manually operated suction isolation valves. Four redundant safety-grade water level sensors (operating in a two-out-of-four logic) at the lower level (0.4 meter) of the RSW pump room will generate a signal to alert the control room operator. If the control room operator fails to take appropriate action to stop the water flow, the second set of level sensors will actuate when the water reaches the 1.5 meter level of the room. At this level, the sensors (operating in two-out-of-four logic) not only send an alarm signal to the operator but also trip the affected RSW pump and close all the isolation valves. The upper level sensors are diverse from the lower level sensors.

It is assumed that one division of RSW is lost in the event of flooding in the RSW pump room. Failure of the watertight doors between the RSW divisions will allow the flood water into a second, or third RSW pump room. Failure of all RSW pump rooms will require core cooling from the power conversion system or the AC independent water addition system (ACIWA).

A large pipe break in the RSW supply line in the RSW pump room is considered to be the worst case flooding in the RSW pump house. The description of events follows:

- (1) A large RSW pipe break occurs in an RSW pump room (flooding initiator).
- (2) Four redundant safety grade water level sensors located at the 0.4 m level detect and alert the control room operator about flooding (detection).
- (3) The operator investigates the presence of water and isolates the flooding by tripping the affected pump and/or closing the manually operated suction isolation valve (flooding prevention).
- (4) If the first level of detection fails or the operator fails to isolate the flowing water, then water continues rising in the room and the second set of diverse sensors located at 1.5 meters detects the water and trips the affected pump and closes the five automatic motor operated valves in the RSW division. Meanwhile the signal alerts the control room operator of the flooding condition (flooding prevention).
- (5) If the operator is successful in isolating the flooding, one safety division is assumed lost, otherwise the loss of all three safety divisions may occur (flooding mitigation).
- (6) In the unlikely event that the flood is not mitigated by automatic means or operator action, the water rises to the electrical and HVAC room and floods the entire RSW compartment. Water exits the compartment through the HVAC intake and discharge vents.
- (7) Failure of a watertight door at the pump room or the electrical and HVAC room could allow a second division of RSW to become flooded.

- (8) Common cause failure of multiple watertight doors will disable the entire RSW system, forcing the plant to rely on the Power Conversion System and the ACIWA.
- (9) Reactor safe shutdown using available equipment (reactor shutdown).

The core damage probability for an RSW pump house flood is estimated to be extremely small.

19R.6.1 Results

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

The results from the ABWR probabilistic risk analysis are shown in Table 19R-6 for the turbine, control and reactor buildings, and the RSW pump house. This conservative bounding analysis shows that the CDF for internal flooding is very small and is less than the total plant CDF.

19R.6.2 Insights Gained from Analysis

STP DEP 19R-1

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

Completion of the ABWR probabilistic flooding analysis has led to the following insights on the flooding mitigation capability of the ABWR:

- (1) *The ABWR due to its basic layout and safety design features is inherently capable of mitigating potential internal flooding. Safety system redundancy and physical separation for flooding by large water sources along with alternate safe shutdown features in buildings separated from flooding of safety systems give the ABWR significant flooding mitigation capability. Also, fire protection features such as floor and wall penetrations and fire barriers help to contain potential flood sources.*
- (2) *Due to the inherent ABWR flooding capability discussed above, only a small number of flooding specific design features must be relied on to mitigate all potential flood sources. The flood specific features are: watertight doors on control and reactor building entrances, ECCS rooms, and RCW rooms, and all levels of the RSW pump house; floor drains in reactor and control building; RSW pump trip, redundant isolation valve closure ~~and actuation of anti-siphon capability~~ on high water level in the RCW rooms or RSW pump rooms; CWS pump trip and valve closure on high water level in the condenser pit; and sump overfill lines on floor B1F of the reactor building.*
- (3) *All postulated floods can be mitigated without taking credit for operation of sump pumps.*

- (4) *While timely operator action can limit potential flood damage, all postulated floods can be adequately mitigated (from a risk perspective) without operator action.*

19R.6.4 Operator Actions

STP DEP T1 5.0-1

The following site-specific supplement addresses the STP 3&4 design that has all openings to safety-related buildings below the Design Basis Flood (DBF) level closed.

- (4) Close-Verify all watertight doors at the entrance to the control room area are closed if floods in the turbine building result in service building flooding.

The following site-specific supplement presents the analysis performed for the RSW pump house internal flood.

- (6) A leak in the RSW supply line before the manually-operated, locked open suction isolation valve cannot be isolated. This line is designed to break exclusion criteria which minimizes the likelihood of a major failure or leak.

In the PRA, operator action of responding to a flood alarm has been modeled. Floods in the turbine, control and reactor buildings, or the RSW pump house result in alarms in the control room. It is assumed that flood procedures exist and operators are well trained to respond to flooding events. The operator failure probability depends upon the time available for taking action and are conservative values based on engineering judgment. The operator actions are not important in the sense that automatic actions will prevent core damage. However, timely operator action could limit the consequences of flood events.

19R.6.6 Conclusions

The following site-specific supplement addresses the STP site being a high PCHS design.

The conclusions from the ABWR probabilistic flooding analysis is that the risk from internal flooding is acceptably low. The estimated core damage frequency from all internal flood sources is very small for a low PCHS and slightly higher for a the high PCHS design of STP 3 & 4.

19R.7 External Flooding Evaluation

STP DEP T1 5.0-1

Summarized in the sections below is the probabilistic risk assessment (PRA) external flooding assessment for the STP 3 & 4 plants. External flooding is defined as intrusion of water from sources outside of plant buildings such that the ability of the plant to achieve safe shutdown is affected.

19R.7.1 Methodology

STP DEP T1 5.0-1

The “Addenda to ASME/ANS RA-S–2008, Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME/ANS RA-Sa–2009” (Reference 19R-5), contains screening criteria for external events other than fire and seismic events in Subsection 6-2.3. In NUREG-1407 (Reference 19R-6), the NRC recommended a similar set of screening criteria for the Individual Plant Examination of External Events (IPEEE) required of all operating nuclear power plants.

In ASME/ANS RA-Sa–2009, Subsection 6-2.3, the fundamental criteria for screening external events other than fire and seismic events are as below:

“There are three fundamental screening criteria embedded in the requirements here, as follows. An event can be screened out either

- a. if it meets the criteria in the NRC’s 1975 Standard Review Plan (SRP) or a later revision; or
- b. if it can be shown using a demonstrably conservative analysis that the mean value of the frequency of the design-basis hazard used in the plant design is less than $\sim 10^{-5}/\text{yr}$ and that the conditional core damage probability is $< 10^{-1}$, given the occurrence of the design-basis hazard event; or
- c. if it can be shown using a demonstrably conservative analysis that the CDF is $< 10^{-6}/\text{yr}$.”

The STP design for safety-related systems, structures and components satisfies the requirements of Standard Review Plan 3.4.2, Revision 3 which was in effect at the time of the Combined License Application. Criterion (a) of ASME/ANS RA-Sa–2009 Subsection 6-2.3 is satisfied for the external flood scenarios and these events are screened from detailed quantitative evaluation.

19R.8 References

The following site-specific supplement provides references.

- 19R-1 STPEGS 1&2 UFSAR Section 2.4, Hydrologic Engineering, Revision 13.
- 19R-2 "Prediction of Embankment Dam Breach Parameters," DSO-98-004, Dam Safety Office, Water Resources Research Laboratory, US Department of the Interior, Bureau of the Interior, July, 1998.
- 19R-3 South Texas Project Electric Generating Station Level 2 Probabilistic Safety Assessment and Individual Plant Examination, Revision 0.
- 19R-4 ANS 2.8-1992, Determining Design Basis Flooding at Power Reactor Sites, American Nuclear Society, 1992.
- 19R-5 Addenda to ASME/ANS RA-S-2008, Standard for Level 1/ Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME/ANS RA-Sa-2009, American Society for Mechanical Engineers and American Nuclear Society, February, 2009.
- 19R-6 "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," Report NUREG-1407, U.S. Nuclear Regulatory Commission (1991).

Table 19R-1 Sources of Water

Source	Capacity	Flow Rate	Turbine Building	Control Building	RSW Pump House	Reactor Building	Service Building	Radwaste Building
Reactor Service Water (RSW)	Unlimited	499.67 675 liters/sec/div. pump. (7,920 10,700 GPM/div. pump.) (6 pumps)		X	X			
Turbine Service Water	Unlimited	42,648 1,278 liters/s/pump (45,000 20,255 GPM/Pump) (3 pumps)	X					
Circulating Water (CW)	Unlimited	42,648 18,927 liters/s/pump (200,000 300,000 GPM/pump) (34 3 pumps)	X					
Fire Water	1,249,182 liters/tank (330,000 gal/tank) (2 tanks)	9,469 4.6 liters/s/2-pumps (450 2788 GPM/ pump) (2 pumps)	X	X	X	X	X	X
Reactor Building Cooling Water (RCW)	257,407 liters/div. (68,000 gal/div)	360.87 4040 liters/s (A,B) (5,720 6252 GPM (A,B) 305.36 344 liters/s (C) (4,840 5466 GPM (C)		X		X		X
HVAC Normal Cooling Water (HNCW)	113,562 liters (30,000 gal)	406.94 286 liters/s (4695 4535 GPM) (5 pumps)		X		X	X	X
HVAC Emergency Cooling Water (HECW)	113,562 liters (30,000 gal)	7.57 - 43.88 15.77 liters/s (120- 200 250 GPM) (Chilled) 21.51-35.58 liters/s (341-564) GPM) (Condenser)		X		X	X	X

Table 19R-1 Sources of Water (Continued)

Source	Capacity	Flow Rate	Turbine Building	Control Building	RSW Pump House	Reactor Building	Service Building	Radwaste Building
Makeup Water (Condensate)	2,108,468 liters (557,000 gal)	104.10 liters/s (1,650 GPM)	X			X		X
Makeup Water (Purified)	757,080 liters (200,000 gal)	19.43 liters/s (308 GPM)				X		
Turbine Cooling Water (TCW)	378,540 liters (100,000 gal)	1829.64 2524 liters/s (29,000 40,000 GPM)	X					
Feedwater	757,080 liters	2110.82 2750 liters/s (33,600 43,600 GPM) (4 pumps)	X				X	
City Water Suppression Pool	Unlimited 3,579,754 liters (947,674 gal)	12.62 liter/s			X			

Table 19R-6 Internal Flooding Core Damage Frequency (CDF)

The information in this table is incorporated by reference with the following site-specific supplement: Low PCHS is not applicable to STP 3 & 4. The results for the site-specific RSW pump house internal flooding core damage frequency (CDF) applicable to the high PCHS of the STP 3&4 site is contained in plant-specific documentation that is not part of the FSAR.

Building	CDF (per reactor year)	
	Low PCHS*	High PCHS*
Turbine	Not Applicable	
Control	Not Applicable	
Reactor	Not Applicable	
RSW Pump House	Not Applicable	**
Total	Not Applicable	

* ** Not part of FSAR (contained in plant-specific PRA documentation).

Table 19R-7 ABWR Features to Prevent/Mitigate Flooding (Continued)

Feature	Benefit
RSW Pump House	
RSW pump rooms and electrical and HVAC rooms have watertight doors.	Prevent flooding in one division from affecting other divisions.
Watertight doors in the RSW pump house are alarmed in the Control Room if not dogged closed	Additional barrier to ensure watertight integrity between pump rooms is maintained.
Floor drains route water to first floor (RSW pump rooms).	Protects equipment in rooms from water damage and directs water to sump pumps.
RSW pump rooms have sump pumps.	Remove flood water from room to prevent damage to equipment.
RSW pump room floor water level sensors alarm at 0.4 meter and trip RSW pumps and close redundant isolation valves at 1.5 meters in affected division.	Alert operator to RSW leak and shutoff RSW supply if flooding were to continue.
<i>RCW/RSW room floor water level sensors alarm at 0.4 meter and trip RSW pumps and close <u>redundant</u> isolation valves at 1.5 meters in affected division.</i>	<i>Alert operator to RCW leak and shutoff RSW supply if flooding were to continue.</i>

Figure 19R-6 Reactor Building Arrangement - Elevation 12300 mm (1F)

Figure 19R-6 is replaced by Chapter 21, Figure 1.2-8.

Figure 19R-7 Turbine Building Flooding (Low PCHS)

The information in this figure is incorporated as a site-specific supplement to the reference ABWR DCD.

Note that this figure does not apply to the high PCHS design of STP 3 & 4. This figure is deleted.