3.4 Water Level (Flood) Design

In accordance with GDC 2 and RG 1.29, the Seismic Category I structures, systems, and components (SSC) identified in Table 3.2.2-1 can withstand the effects of flooding due to natural phenomena or onsite equipment failures, without losing the capability to perform their safety-related functions. A description of these structures is provided in Section 3.8. The U.S. EPR design meets the requirements of GDC 4 because safety-related SSC accommodate the effects of discharged fluid resulting from the high- and moderate-energy line breaks postulated in Sections 3.6.1 and 3.6.2. The criteria in RG 1.59 and ANSI/ANS-2.8-1992 "Determining Design Basis Flooding at Power Reactor Sites" (Reference 1) are used to establish the probable maximum flood (PMF), probable maximum precipitation (PMP), seiche, and other hydrologic considerations. The flood protection measures for Seismic Category I SSC are designed in accordance with RG 1.102. Section 2.4 provides further information on hydrologic engineering. Section 2.5 provides information on safe shutdown earthquake ground motion. Section 3.8 provides information on the design of Seismic Category I structures. The risk assessment for external and internal flooding is provided in the U.S. EPR probabilistic risk assessment addressed in Chapter 19.

3.4.1 Internal Flood Protection

The U.S. EPR includes measures for protecting safety-related SSC against the effects of internal flooding from postulated flooding sources. These measures also protect safety-related SSC from flooding from non-safety-related SSC that are not required to be protected from either internal or external flooding. Because of these measures, a failure of components due to an internal flooding event will not prevent safe shutdown of the plant or mitigation of the flooding event. The nuclear island general arrangement drawings in Section 3.8 are a useful reference for the following description of protective measures for internal flooding.

The principal protective measure for Seismic Category I buildings is physical separation of the redundant safe shutdown systems and components. The safeguard buildings (SB), emergency power generating buildings (EPGB), and essential service water pump buildings (ESWPB) are Seismic Category I buildings designed with complete divisional separation of the four divisions of safety systems and are therefore consistent with an N+2 safety concept. With four divisions, one division can be down for maintenance and one can fail to operate due to an event such as internal flooding, while the remaining two divisions are available and sufficient to perform the necessary safety functions. The fuel building (FB) is designed with complete separation into two divisions below elevation +0 feet 0 inches such that in the event of an internal flood, the flood is restricted to one division of the FB while the other division is available and sufficient to perform the necessary safety functions. Each of the two divisions is designed to fulfill the safety function assuming the other division is not available. These buildings are designed such that the consequences of an internal hazard are contained within the division of hazard origin and are not allowed to propagate to other divisions. Consequently, in a large internal flooding event in buildings with divisional separation safety-related SSC within the affected division are assumed to be flooded. The plant arrangement provides divisional separation walls to physically separate the redundant trains of safe shutdown systems and components. A combination of fluid diversion flow paths and passive features contain the water within the affected division. Features credited in the analysis will be verified by walk-down.

Division walls below elevation +0 feet, 0 inches (hereinafter +0 feet) provide separation and serve as flood barriers to prevent flood waters spreading to adjacent divisions. These division walls are watertight, have no doors, and a minimal number of penetrations all of which are watertight up to elevation +0 feet. Water is directed within one division to the building elevations below +0 feet, where it is stored. Above elevation +0 feet, a combination of watertight doors and openings for water flow to the lower building levels prevent water ingress into adjacent divisions. Watertight doors have position indicators for control of the closed position and are periodically inspected and maintained so that they remain capable of performing their intended function. Existing openings (e.g., stair cases, elevator shafts, and equipment openings) are credited as water flow paths. Watertight doors are designed to functional requirements such as leak-rate limits, door-closure indication, door-seal aging-degradation characteristics, and maintainability. Maintenance requirements are based on manufacturer recommendations and maintenance procedures are written by COL applicants in accordance with their respective regulatory approved maintenance programs.

A COL applicant that references the U.S. EPR design certification will include in its maintenance program appropriate watertight door preventive maintenance in accordance with manufacturer recommendations so that each Safeguards Building and Fuel Building watertight door above elevation +0 feet remains capable of performing its intended function.

Flooding pits with burst openings collect and direct water flow to lower building levels. Rooms within divisions have interconnections so that the maximum released water volume can be distributed and stored in the lower building levels of the affected division. Interconnections include doors with flaps, wall openings, and other wall penetrations that are not required to be sealed. Elevated thresholds, curbs, and pedestals are provided as necessary.

In Seismic Category I buildings that are not designed with divisional separation, e.g., the Reactor Building (RB), the layout allows water released inside the building to flow to the lower level of the building. In containment, water flows down to the in-containment refueling water storage tank (IRWST). In the annulus, water flows to the bottom level where it is stored. Safety-related SSC in these buildings are located above the maximum water level, protecting them from the effects of flooding or are qualified for submergence in accordance with Section 3.11 and Appendix 3D. Where equipment could be submerged, it will be identified and demonstrated to be qualified for the duration required and documented in an Equipment Qualification Data Package (EQDP). Locations of safety-related SSC and features provided to withstand flooding will be verified by walk-down.

Leak detection and isolation measures mitigate the consequences of postulated pipe ruptures. Water level instrumentation and other leak detection measures detect pipe ruptures that could result in internal flooding. These leak detection systems provide a signal to automatically isolate the affected system or to provide indication to the main control room (MCR) to initiate operator action from within the MCR or locally. Section 3.6 provides further information on protection mechanisms associated with the postulated rupture of piping.

The nuclear island drain and vent system (NIDVS) prevents backflow of water from affected areas of the plant that contain safety-related equipment. The NIDVS is conservatively considered not available for reducing water volume by the respective sump pumps, and floor drains are assumed to be plugged.

3.4.2 External Flood Protection

The Seismic Category I SSC listed in Section 3.2 can withstand the effects of external flooding due to natural phenomena and postulated component failures. Seismic Category I structures, provide protection from external floods and groundwater by incorporating the following external flood protection measures:

- The PMF elevation of the U.S. EPR generic design is one foot below finished yard grade (as noted in Section 2.4).
- The maximum groundwater elevation for the U.S. EPR generic design is 3.3 ft below finished yard grade (as noted in Section 2.4).
- The finished yard grade slopes away from Seismic Category I structures so that external flood water flows away from these structures.
- No access openings or tunnels penetrate the exterior walls of the Nuclear Island or any other Seismic Category I structures below grade.
- Portions of Seismic Category I structures located below grade elevation incorporate the use of waterstops and waterproofing to mitigate environmental deterioration of exposed surfaces and thereby minimize long term maintenance.
- Exterior wall or floor penetrations of Seismic Category I structures below grade have watertight seals.

- Waterproofing and dampproofing systems shall be applied per the International Building Code, Sections 1805.2 and 1805.3 (Reference 2).
- Waterproofing and dampproofing materials selected for use in horizontal applications will have the physical properties to achieve the required static coefficient of friction specified in Table 2.1-1.
- The roofs of Seismic Category I structures prevent the undesirable buildup of standing water in conformance with RG 1.102. The roofs of the structures do not have parapets that could collect water.
- The maximum rainfall rate for roof design is 19.4 inches per hour and the maximum static roof load because of snow and ice is 100 pounds per square foot.
- Seismic Category I structures can withstand hydrostatic loads resulting from groundwater pressure and external flooding.

A COL applicant that references the U.S. EPR design certification will design the watertight seal between the Access Building and the adjacent Category I access path to the Reactor Building Tendon Gallery. Watertight seal design will account for hydrostatic loads, lateral earth pressure loads, and other applicable loads.

The reinforced concrete Seismic Category I structures, together with the waterproofing and sealing features described above, provide hardened protection from the effects of external flooding for safety-related SSC as defined in RG 1.59. Additionally, the external flood protection measures described above protect against flooding from postulated failures of onsite storage tanks. Further information on the potential causes of external flooding from natural phenomena is provided in Sections 2.4.1 through 2.4.14.

3.4.3 Analysis of Flooding Events

3.4.3.1 Internal Flooding Events

An internal flooding analysis was performed for Seismic Category I structures to determine the adequacy of the design to protect safety-related SSC from the effects of internal flooding caused by postulated component failures. The internal flooding analysis demonstrates that internal flooding resulting from a postulated initiating event does not cause the loss of equipment required to achieve and maintain safe shutdown of the plant, emergency core cooling capability, or equipment whose failure could result in unacceptable offsite radiological consequences. Section 7.4 describes the safety-related systems and components required for safe shutdown of the plant. The internal flooding analysis also describes the flooding protection measures that mitigate the consequences of flooding in areas that contain safety-related systems and components.

Sources of flooding in the internal flooding analyses include:

- High-energy piping (breaks and cracks).
- Through-wall cracks in seismically supported moderate-energy piping.
- Breaks and cracks in non-seismically supported moderate-energy piping.
- Improper system valve alignments.
- Tanks.
- Fire protection systems.
- Water from adjacent buildings.

The internal flooding analysis is conducted on a level-by-level and room-by-room basis for the Seismic Category I structures for the postulated flooding events. The analysis consists of the following:

- Identification of safety-related equipment.
- Identification of potential flooding sources.
- Determination and comparison of flood water volumes and building volumes.
- Evaluation of effects on required equipment.
- Determination of the need for protection and mitigation measures.

The following criteria and assumptions are used to determine flood water volumes and flow rates:

- For closed systems and storage tanks, the complete system or tank content is assumed to be released.
- If isolation of the pipe leak or break is assumed, only the released water volume within the operator action time is considered.
- The maximum operational pressure is used to estimate leakage flow rates.
- Released steam is considered to be completely condensed.
- Criteria and assumptions described in Section 3.6 are used to determine break configurations, locations, and flow rates for postulated high- and moderate-energy pipe ruptures.
- Floor drains are assumed to be plugged and sump pumps are assumed to be not available for reducing flood water volume.
- Volume of water released from operation of the fire protection system is determined based on 500 gpm for 2 hours.

The internal flood analysis relies upon leak detection instrumentation, automatic isolation of systems and components, and operator action to limit the volume of released water from pipe ruptures in water-carrying systems. The following approaches regarding flooding duration are assumed:

- For leaks and breaks that are detected by instrumentation and controls for which an automatic isolation is provided, the flooding duration spans the time it is detected through the duration of the automatic isolation.
- For leaks and breaks that can be detected by signals in the MCR, for which isolation by operator action from the MCR is provided, the flooding duration spans the time from when the first alarm in the MCR is received through a thirty minute operator action time from the MCR.
- For leaks and breaks that can be detected by signals in the MCR and for which isolation by local actions is provided, the flooding duration spans the time from when the first alarm in the MCR is received through a one hour local action time (e.g., the time for personnel to perform a manual valve isolation).
- Leaks and breaks that cannot be detected or isolated are assumed to release the entire water inventory if the discharge is not otherwise limited.

3.4.3.2 External Flooding Events

The Seismic Category I structures can withstand the hydrostatic effects associated with the PMF and maximum groundwater elevation given in Section 3.4.2. These hydrostatic effects are transformed into loads and loading combinations and factored into the structural design of Seismic Category I structures as addressed in Section 3.8.

The Seismic Category I structures are not designed for dynamic effects associated with external flooding (e.g., wind waves and currents) because the design basis flood level is below the finished yard grade.

The types of external flood-producing phenomena and combinations of flood-producing phenomena that are considered in establishing the design basis flood are described in Section 2.4. A COL applicant that references the U.S. EPR design certification will confirm the potential site-specific external flooding events are bounded by the U.S. EPR design basis flood values or otherwise demonstrate that the design is acceptable.

3.4.3.3 Reactor Building Flooding Analysis

Containment

The lowest elevation safe shutdown systems and components relevant to internal flooding inside containment include the safety injection system/residual heat removal system (SIS/RHRS), containment isolation valves, and reactor protection system.

Equipment and components of these systems that are sensitive to flooding are generally located above the maximum internal flood level. This arrangement provides a margin between the normal operation maximum water level of the IRWST and these components, in order to store water released from postulated pipe failures and avoid a consequential failure by flooding.

In the event of piping failures, water flows directly to the IRWST while steam condenses on structures (e.g., concrete walls, containment walls, ceilings, and floors) and flows to the IRWST.

The analysis is focused on postulated piping failures that result in the largest volume of released water inside containment. Table 3.4-1 is a compilation of water-carrying piping systems located in the RB containment and RB annulus which were considered as potential internal flooding sources in the flooding analysis of these buildings. The following cases are enveloping scenarios for released water volume in containment:

- Water from a large break loss-of-coolant-accident (LOCA) in the reactor coolant pressure boundary (i.e., release of reactor coolant system inventory, pressurizer water volume, and the inventory of accumulators).
- Operation of the fire protection system.

A large break LOCA is determined to be the bounding case for the maximum released water volume in containment. This event results in the release of 20,659 ft3 (154,540 gallons) of water which, because of the design features of the containment building is directed down to the IRWST, subsequently collecting on elevation -7'-6½" and rising to elevation -6'-2". Safety-related SSCs are either located above this flood level or are qualified for submergence in accordance with Section 3.11 and Appendix 3D. Where equipment could be submerged, it will be identified and demonstrated to be qualified for the duration required and documented in an Equipment Qualification Data Packages (EQDP). Table 3.2.2-1 provides a list of safety-related SSCs located in the RB containment and RB annulus. No other postulated pipe breaks, through-wall cracks, or operation of the fire protection system inside containment release a volume of water which could cause flooding of safety-related SSC.

Inside containment, leakages are integrally detected by measuring humidity, temperature, condensate flow, and water levels in drain and vent collection tanks or sumps. Depending on the leak and break size and the affected system, the protection system initiates automatic measures as required to cope with the event (e.g., LOCA, main steam line break, or main feedwater line break). A NIDVS sump located at level -7 feet, 6-1/2 inches is equipped with safety-related Seismic Category I level instrumentation to initiate alarms in the MCR for a filled sump and large flooding event. These alarms notify the MCR operator to begin action to isolate the flooding sources.

To avoid water ingress into the corium spreading area, which could produce a steam explosion in case of an accident, the venting area from the spreading compartment has a watertight door.

Reactor Building Annulus

Below elevation +0 feet, the annulus between the Shield Building and the Containment Building is a single volume; therefore, it is considered one room for flooding protection purposes. Water released from a specific location flows down in the annulus and collects on the bottom level. Because high-energy piping (e.g., main steam lines and main feedwater lines) is routed inside guard pipes, there is no water accumulation in the annulus due to their failure. Therefore, the analysis is focused on water-carrying systems without guard pipes. Table 3.4-1 lists the water-carrying piping systems in the annulus evaluated in the flooding analysis. The internal flooding sources inside the reactor building annulus are the moderate-energy water-carrying piping systems. Since these piping systems are seismically designed inside the annulus, through-wall leakage cracks were postulated. The released water from these pipe failures is limited by either operator action to isolate the source or by the limited volume of water contained in a closed system. The systems listed in Table 3.4-1 do not release an amount of water which would flood safety-related SSC and the resulting flood level is below elevation +0 feet. The bounding internal flooding source becomes operation of the fire protection system which occurs during manual fire fighting by hose stream. The released water during fire fighting does not flood safety-related SSC and the resulting flood level is below +0 feet.

Inside the annulus, only the plug boxes of cable penetrations for electrical and instrumentation and control equipment located above elevation +16 feet, 10-3/4 inches could be affected by flooding. In the event of operation of the fire water distribution system, the annulus ventilation system supply is lost because the annulus ventilation duct is flooded through the grids. Furthermore, the normal operating mode of the SB controlled area ventilation system could be lost because of water entering through the inspection openings. These consequences are acceptable because the safety-related functions are fulfilled by the annulus ventilation system exhaust trains which maintain sub-pressure in the annulus, the accident mode of the SB controlled area ventilation system which maintains sub-pressure in the SBs, and the recirculation mode of the SB controlled area ventilation system which maintains ambient conditions in the SBs.

Leak detection inside the annulus consists of safety-related Seismic Category I level measurements in the NIDVS sump located on elevation -14 feet, 1-1/4 inches. These level measurements initiate an alarm in the MCR for a filled sump (considered as the first alarm for initiating the operator action time for isolation) and an alarm for a flooding event above floor level -14 feet, 1-1/4 inches.

The hydrostatic water loads corresponding to an elevation of +0 feet are taken into account in the structural design of the annulus walls and for the watertight design of cable and piping penetrations below this elevation.

The annulus is not divisionally separated; however, redundant divisions are separated in fire zones. In case of fire fighting or a postulated piping failure, overlapping areas exist where redundancies belonging to another division could be indirectly impacted by water flow through the horizontally arranged fire separation structures on the inner and outer walls of the annulus. In these cases, the plug boxes of cable penetrations for electrical and instrumentation and control equipment are designed to withstand this water flow.

3.4.3.4 Safeguard Buildings Flooding Analysis

The arrangement of the SBs provides physical separation of the redundant safe shutdown systems and components using structural barriers. The building layout directs released water within one SB to building levels below elevation +0 feet.

Below Elevation +0 Feet, 0 Inches

Division walls below elevation +0 feet, 0 inches provide separation and serve as flood barriers to prevent the spread of flood water to the adjacent SB. Below elevation +0 feet, SB-1 and SB-4 are connected to the Fuel Building (FB) via passageways. Postulated piping failures below elevation +0 feet could lead to consequential failures in only one division. Common flooding of SB-1 and the left hand side of the FB (i.e., FB-1, see Section 3.4.3.5 and the general arrangement drawings in Section 1.2), or of SB-4 and the right hand side of the FB (i.e., FB-2, see Section 3.4.3.5 and the general arrangement drawings in Section 1.2), is acceptable, because they belong to the same division.

Relevant component and system piping failures considered in the analysis of these building levels include loss of one demineralized water pool, a leak in the SIS suction line from the IRWST, a pipe leak in the SIS/RHRS during normal operation, and a break in the fire water distribution system piping. The bounding flooding source below elevation +0 feet is considered to be a postulated break in the main piping of the fire water distribution system. The volume of released water is based on an assumed full break in the piping, a flow rate limited by the maximum pump capacity, and an operator action time of thirty minutes to isolate the system after receiving the first alarm in the MCR. At these levels, the rooms within one division have sufficient interconnections so that the maximum released water volume can be stored within the division. Based on the available free volume of these building levels in each division, the maximum released water volume can be contained within the affected division.

Elevation +0 Feet, 0 Inches

At elevation +0 feet, 0 inches there is no physical separation of divisions with respect to flooding. A corridor connects the SBs and the FB. To avoid water ingress into adjacent divisions at this elevation and above, a combination of watertight doors, existing openings (e.g., stairwells), and designed openings for water flow to the lower building levels are provided.

Relevant component and system piping failures considered in the analysis for this elevation include failures in the essential service water system (ESWS) and component cooling water system (CCWS) heat exchangers, leaks in the emergency feedwater system, leaks in the CCWS, and pipe failure in the fire water distribution system.

A postulated pipe break or erroneous valve alignment in the ESWS has the potential to impact more than one division. The ESWS piping penetrates the SBs at elevation -14 feet, 9-1/4 inches and is routed to the CCWS heat exchangers at elevation +0 feet. The worst case scenario assumed in the analysis is an erroneous valve alignment where the CCW heat exchanger is left open after plant maintenance, resulting in the entire cross section of the associated ESW line releasing water at elevation +0 feet. To cope with nonclosure of the heat exchanger or a large break in the ESWS piping, the associated motor-driven ESWS pump discharge isolation valve is automatically closed and the ESWS pump is tripped to limit the flooding volume in the affected SB. No operator action is required to isolate the ESWS in a large flooding event.

Safety-related detection and isolation signals are provided in the nuclear island drain and vent system in each SB to initiate an alarm in the MCR and automatically isolate the ESWS. The level sensors that actuate the isolation are above the floor level so only large flooding events can initiate an isolation.

Flooding protection measures mitigate consequences resulting from a postulated failure in the fire water distribution system. A watertight physical protection door prevents water ingress into neighboring divisions through the interconnecting passageway between SB-1 and SB-2. This door is provided with position indication and monitoring of the locking and bolting status for control of the closed position. In the event of flooding, the door is considered closed. A flooding pit with a burst panel below the interconnecting passageway allows water to flow to lower building levels. This arrangement also exists for the passageways between SB-3 and SB-4 and between SB-2 and SB-3.

Elevation +15 Feet and Above

Physical separation for flooding is not provided for elevations +15 feet and above. Therefore, protection measures restrict flooding to the SB where the flooding event was initiated. Sufficient openings and thresholds direct water flow to the lower building levels.

Potential sources of flooding located on these building levels include the demineralized water distribution system, safety chilled water system (SCWS), fire water distribution system, CCWS including surge tank, and the potable and sanitary water disposal system. These systems have been reviewed for possible effects on the MCR and remote shutdown station (RSS) because they are located above the MCR, and measures are provided to protect the MCR and RSS from flooding. No water-carrying piping systems are located in the MCR or RSS. Thresholds are provided for doors entering the MCR and water resistant doors are provided for entry doors to the RSS. For the fire water distribution system, demineralized water distribution system, and the CCWS, multiple openings and flow paths direct flood water from pipe breaks to lower building levels. Surge tank water tightness is provided by a steel liner and leak detection system.

The SCWS is a closed system with manual makeup and, therefore, contains a limited volume of water. In the lower levels of the Safeguard Buildings the contents of two cross-tied SCWS trains is assumed to be released in the event of a pipe failure and directed within the division to the lowest building level through large openings and staircases. At higher building elevations (e.g., elevation +69 feet in SB 2 and SB 3) the released water volume from a pipe failure is also conservatively assumed to be the contents of two cross-tied SCWS trains. A common loss of the main control room air conditioning system (CRACS) in SB 2 or SB 3 is prevented by placing equipment sensitive to flooding above the expected flood water height resulting from the water released remaining in the area of the CRACS equipment rooms and adjoining service corridor.

Leak detection is provided by level measurement in the NIDVS building sump. Specific leak detection measurements near the MCR detect pipe failures in the potable and sanitary water distribution system. Two remotely operated valves in the potable and sanitary water disposal system in SB-1 close automatically when the filled level is reached in the NIDVS building sumps. Generally, the water released from a break in the potable and sanitary water distribution system drains toward the NIDVS building sumps. However, for the restrooms this is not appropriate because of the possibility of sewage water ingress into the NIDVS. Therefore, there are additional local detection measures in rooms adjacent to the MCR, consisting of two level measurements that provide a close signal to the isolation valves in SB-1 and an alarm to the MCR. The released water can be stored in the affected area until system isolation without flooding to safety-related areas.

Fire fighting in the vicinity of the MCR, RSS, and the HVAC floor above the MCR complex is considered. Within a SB, the water released because of fire fighting is enveloped by the released water volumes from the postulated pipe failures. The flooding analysis of larger rooms (e.g., cable rooms, MCR, tagging room, and computer rooms) assumes that the fire is not extinguished by mobile extinguishers and that the wall hydrants for manual fire fighting are used. Individual extinguishing areas are limited to one SB; consequently, fire fighting will be performed from one SB. Divisional separation for flooding exists in the case of fire fighting by water. The effects of the extinguishing water are restricted to the rooms with the fire event and, in some cases, to adjacent corridors or rooms through the existence of thresholds and doors designed for a water column higher than the expected flood level.

Valve Compartment Flooding Analysis

The general flooding protection concept for the valve compartments is based on pressure relief openings for postulated breaks in the high-energy piping with the largest nominal diameter. This concept restricts the loadings on the outer reinforced concrete structure of the feedwater and the main steam valve compartments. The relevant effects of pipe breaks are also restricted to one of these valve compartments. Water flows from these release openings in the wall or bottom slab of the valve compartments and drains from the maintenance areas down the outer wall of the SBs. This drainage route also exists for postulated pipe failure outside the valve compartments in the pipe routing area. Water is prevented from spreading to other parts of the SB from the areas in front of the valve compartments by watertight doors leading to adjacent rooms.

Each feedwater and main steam valve compartment is separated from the others by building structures. Penetrations in these building structures (e.g., doors, piping and cable penetrations, and pressure relief openings) are designed for pipe failure in one compartment or in the pipe routing area in front of the compartments where no water ingress occurs. There are no connections between the different valve compartments via the building drain system.

The relevant case considered for the feedwater valve compartment is protection against the effects of water outflow, which results from a postulated overfilling of a steam generator. In this event, consequential flooding of the isolation and control valves of the feedwater system must be avoided for isolation of the affected steam generator. The motors of the feedwater isolation and control valves are located at least 6 feet, 6-3/4 inches above floor elevation +55 feet, 1-1/2 inches. In these compartments, no other safety-related components are located below this elevation. To avoid flooding the motors, burst flaps in the compartment wall are capable of releasing the complete water flow rate. The burst flaps open at a water level below the elevation of the motors, which provides a margin before water reaches the motors. Pipe failure is detected by changes in system parameters in the feedwater system and level changes in the steam generator. Depending on the size of the pipe failure, automatic measures from the protection system or manual actions from the MCR are initiated for isolation.

For the main steam valve compartments, the relevant case considered for protection of equipment from flooding is a postulated break of the warm-up line. Valve motors are located at least 6 feet, 6-3/4 inches above floor elevation +64 feet, 7-1/2 inches. In these compartments, no other safety-related components are located below this elevation. In case of flooding, the pressure relief opening located in the floor slab of elevation +64 feet, 7-1/2 inches drains the valve compartment. The pressure relief opening opens from a water column that provides a margin prior to flood waters reaching the motors. Pipe failure is detected by changes of feedwater system parameters and by temperature measurement in the compartment. Depending on the size of the pipe failure, automatic measures from the protection system or manual actions from the MCR are initiated for isolation. Water from postulated failures in the SCWS is enveloped by the relevant cases above.

Postulated piping failures in the valve room for the steam generator blowdown system are not considered relevant to the flooding analysis because protection of this equipment is not necessary for safe shutdown. However, the released water will flow through the provided pressure relief opening to the service corridor, where it drains to the maintenance area and then flows down the outer SB wall.

In the event of fire in one valve compartment, the fire brigade will extinguish the fire using hoses. The maximum flow rate for manual fire fighting by hose streams is enveloped by the flow rates from the postulated pipe failures considered above. If a door is opened to connect the hose to the hydrant inside the SB, the threshold will prevent backflow of extinguishing water into the SBs through the open door.

3.4.3.5 Fuel Building Flooding Analysis

The divisional separation of the FB (see Section 3.4.1) is denoted by referring to the two divisions as FB-1 and FB-2. The upper building levels are not separated for flood protection because of the layout of the fuel pools. The flooding analysis for the FB follows the separation for fire protection, which separates the building into two main fire areas. This principle is followed so that only one division of the building is flooded in the event of postulated pipe failures.

The FB flooding analysis considers the elevation inside FB-1, FB-2, or the area between the shield wall (the structure that protects the FB, RB, and SBs 2 and 3) and the inner decoupled structure of the FB, up to elevation +0 feet. The design of the enclosing walls of these building areas takes this elevation into account. The piping and cable penetrations in these enclosing walls up to elevation +0 feet are designed for water tightness. There are no ventilation penetrations in these walls. The NIDVS is interconnected between the different FB divisions and with the SBs and the Nuclear Auxiliary Building (NAB). Ingress of water by backflow in the system from one area to the others is prevented by redundant check valves in series. Piping penetrations from FB-2 toward the NAB are watertight for an elevation corresponding to building level of +0 feet in the NAB.

The building is designed for the water mass corresponding to one completely filled building area up to elevation +0 feet. The building layout is designed to direct released water within one FB division to the building levels below elevation +0 feet where physical separation exists. FB-1 and FB-2 are connected to SB-1 and SB-4, respectively, via passageways. To avoid water ingress into the adjacent division and in and out of adjacent buildings at elevation +0 feet and above, a combination of watertight doors and openings for water flow to the lower building levels are provided. The doors from the FB to SB-1 and SB-4 at elevations -31 feet, -20 feet, and -11 feet are physical protection doors. These doors are not watertight because the adjacent SB belongs to the same division. Failures in piping systems below elevation +0 feet would lead to consequential failures in only one division, SB-1 and FB-1 or SB-4 and FB-2. Below elevation +0 feet, the rooms within one division have interconnections so that the maximum released water volume can be stored within the division. Interconnections include doors with flaps, burst openings, and other wall penetrations that are not required to be sealed.

Excessive water losses from the fuel pool are avoided by locating piping connections near the top of the fuel pool and by the use of siphon breakers. Any released water is directed within the affected division to the lower building levels where it is distributed between the affected FB and the connected SB (i.e., FB-1 and SB or FB-2 and SB-4). If one fuel pool cooling train is lost because of flooding from a leak in its piping, the train located in the other division is still available.

The bounding flooding source is a postulated break in the main piping of the fire water distribution system. The main fire water distribution system ring header is located in the interconnecting passageway between the FB and SBs. In order to avoid water ingress into the adjacent division, a combination of watertight doors and openings for water flow to the lower building levels are provided. Existing openings are considered as water flow paths when available. The volume of released water is based on an assumed full break in the piping, a flow rate limited by the maximum pump capacity, and an operator action time of thirty minutes to isolate the system after receiving the first alarm in the MCR. Based on the available free volume of the building levels in each division, the water can be stored within the affected division. The FB NIDVS floor drain sump level measurement instrumentation is safety-related Seismic Category I and includes an alarm signaling a flooding event.

The loading pit and transfer pit located above elevation +0 feet are designed with features that minimize their potential as flooding sources in the FB. A retention pit is provided for the loading pit that is capable of storing the contents of the loading pit. Leakage through the docking flange is not postulated because it is equipped with a double bellows with permanent intermediate suction. Potential leaks in the drain line of the loading pit are directed to the retention pit. The leak is isolated from the fuel pool by closing a revolving isolation gate between the loading pit and fuel pool, which is equipped with double seals and intermediate suction. Water released from postulated leaks in the drain line of the transfer pit is directed to the opposite side of the FB by features such as thresholds and overflow cross sections. The leak is isolated from the fuel pool by closing the revolving isolation gate and from the pools inside containment by closing the manual isolation valve of the transfer tube. Leaks can be detected visually by the personnel who perform the fuel transfer and also automatically by fuel pool level measurement.

Large flooding events can lead to loss of one FB division. A large flooding event in FB2 that leads to flooding of the EBS pumps in this division does not defeat the boration function because of the availability of the extra boration train in the other division. In case of a postulated single failure or maintenance on the available extra boration train, boration can still be performed by opening the pressurizer valve and injecting with the medium head safety injection pumps.

The New Fuel Storage Facility (NFSF) is protected from flooding by door thresholds and the nearby equipment opening in the floor outside the NFSF which drains away any released water in the vicinity of the NFSF. Water is also prevented from entering the NFSF from above by hatch covers and curbing. The water released during manual fire fighting by hose streams is enveloped by the higher flow rates and released water from postulated pipe breaks. Individual extinguishing areas are limited to one safety fire zone (i.e., FB-1 or FB-2); therefore manual fire fighting will be performed from one safety fire zone. Divisional separation for flooding exists for assumed manual fire fighting by hose streams.

3.4.3.6 Nuclear Auxiliary Building Flooding Analysis

There are no safety-related structures, systems or components that must be protected from flooding in the Nuclear Auxiliary Building (NAB). Physical separation exists below elevation +0 feet between the NAB and the FB and between the NAB and SB-4. The building arrangement directs released water from potential internal flood sources to the lowest level of the NAB. Water flows to the lower levels via the building drain system, stairways, and additional drain openings without passing to the FB or SB-4.

Water carrying systems with respect to internal flooding include the fuel pool purification system, steam generator blowdown system, fire water distribution system, CCWS, and the SCWS. Tanks with the highest flooding potential are located below elevation +0 feet.

3.4.3.7 Radioactive Waste Building Flooding Analysis

There are no safety-related structures, systems or components that must be protected from flooding in the Radioactive Waste Building (RWB). The RWB is connected to the NAB below elevation +0 feet. The arrangement of the RWB directs water released from potential sources of internal flooding to the lower levels of the RWB, where it is stored.

3.4.3.8 Emergency Power Generating Buildings Flooding Analysis

The Emergency Power Generating Buildings (EPGBs) house the emergency diesel generators. The station blackout diesels and associated generators are located in the Switchgear Building, which are adjacent to the Turbine Building.

The flooding analysis considers postulated pipe breaks in water-carrying systems within the EPGB, which include the ESWS, fire water distribution system, demineralized water distribution system, and potable and sanitary water distribution system. The bounding internal flooding source is a pipe break in the fire water distribution system, which produces a maximum flood level of 17 feet. The divisional separation wall between the EPGB, is designed as a flood barrier and is higher than the bounding maximum flood level. Piping and cable penetrations between EPGB are watertight. Internal flooding is restricted to one EPGB and the associated safety-related SSC in the flooded division are assumed lost. See Section 3.4.1 for a description of the divisional separation of the EPGB.

The level measurements in the building sumps provide leak detection. The water released during fire fighting within one EPGB is enveloped by the higher flow rates and released water volumes in the postulated pipe failures.

3.4.3.9 Essential Service Water Pump Buildings and Essential Service Water Cooling Tower Structures Flooding Analysis

The ESWPB are physically separated by division and connected to their respective ESW cooling tower. The flooding analysis considers a postulated pipe failure in the ESWS piping to be the bounding internal flooding source. In the event of an ESWS piping failure in the building, the affected division of the ESWS is considered lost. See Section 3.4.1 for a description of the divisional separation of the ESWPB.

3.4.3.10 Ultimate Heat Sink Makeup Water Intake Structure Flooding Analysis

A COL applicant that references the U.S. EPR design certification will perform a flooding analysis for the ultimate heat sink makeup water intake structure based on the site-specific design of the structure and the flood protection concepts provided herein.

3.4.3.11 Permanent Dewatering System

The U.S. EPR design does not have a permanent dewatering system. A COL applicant that references the U.S. EPR design certification will define the need for a site-specific permanent dewatering system.

3.4.4 Analysis Procedures

The analytical methodology used to perform the flooding analyses for external and internal flooding events is described in Section 3.4.3. Section 3.8 provides additional information on the design of Seismic Category I structures against external flooding.

3.4.5 References

1. ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites," American Nuclear Society, 1992.

2. IBC-2009, International Code Council, International Building Code, 2009 edition.

Table 3.4-1—Water-Carrying Piping in the Reactor Building

Description	Reactor Building	
	Containment	Annulus
Fuel pool purification system	X	X
Demineralized water distribution system	X	X
Extra borating system	X	X
Reactor coolant system	X	
Reactor coolant pump seal injection and leak-off system	X	X
Containment heat removal system	X	X
Residual heat removal system	X	X
Medium head safety injection system	X	X
Low head safety injection system	X	X
In-containment refueling water storage tank	X	X
Component cooling water system	X	X
Chemical and volume control system	X	X
Nuclear island drain and vent system	X	X
Nuclear sampling system	X	X
Feedwater system	X	X
Emergency feedwater system	X	X
Main steam system	X	X
Condensate system	X	X
Steam generator blowdown system	X	X
Operational chilled water system	X	X
Secondary sampling system	X	X
Fire water distribution system	X	X
Spray deluge system	X	

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