

NATIONAL MALL UNDERGROUND USACE TECHNICAL REVIEW



**Sectional view represents an early stage concept from 2014. The revised 2017 concept reviewed by USACE has two stories: the upper story for cars would not be flooded; the lower bus level would be used for stormwater storage.*

Prepared for: National Mall Coalition

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EXECUTIVE SUMMARY

The District of Columbia (“District”) experienced a severe storm from June 24-26, 2006, that caused extensive flooding within the Federal Triangle area, resulting in millions of dollars in damage. In response to this flood, several Federal and District agencies formed a Federal Triangle Stormwater Drainage Study Working Group (the “Working Group”) to identify measures to reduce the risk and impact of flooding in the future. The Working Group held a series of meetings that investigated the existing sewer system in relation to the Federal Triangle, determined the storm frequencies and durations to be modeled and analyzed, and identified interior rainfall and the Potomac River as causes of flooding. The Working Group developed and evaluated alternatives to reduce the frequency of stormwater (interior) flooding. One of the potential alternatives analyzed by the Working Group was the construction of underground cisterns beneath the National Mall to capture and store rainfall to minimize future flooding. The Working Group concluded that rainfall storage beneath the National Mall is a viable option for reducing the flood risk in the Federal Triangle.

The National Mall Coalition (the “Coalition”), a non-profit organization, took a further look at this potential underground storage option beneath the National Mall by conceptualizing a solution that includes parking. This proposed solution, called the National Mall Underground (the “Underground”), is a multi-purpose car and tour bus parking garage and National Mall visitor center with access to the Smithsonian museums, national monuments, and other cultural attractions. During heavy rain events, this underground parking structure could function as a stormwater retention reservoir to minimize impacts from stormwater flooding and store water for National Mall irrigation.

In a letter dated May 10, 2017, the Council of the District of Columbia requested support from the U.S. Army Corps of Engineers (USACE) through the Flood Plain Management Services Program (FPMS), for USACE to provide a technical review of the Coalition’s proposal to create an underground reservoir beneath the National Mall that can accommodate a 200-year flood. This effort was funded by the Coalition.

USACE organized a national team of experts consisting of two hydrologists, one structural engineer, two civil engineers, two planners, one construction specialist, and one mechanical engineer, to conduct a technical review of documents provided by the Coalition, including the 2011 Federal Triangle Stormwater Drainage Study (DC Water, 2011), various parking demand studies, project budgets, concept drawings, and cost benefit analysis.¹ The review included two webinars and one joint meeting with the Coalition during which USACE shared its questions and concerns. USACE experts assessed the early stage concept, provided comments and recommendations, and flagged important issues that the Coalition plans to address in coming phases as the project develops.

The Underground offers an innovative, multi-purpose potential alternative for stormwater retention and flood risk management on Constitution Avenue and in the Federal Triangle area. Concurrently, it could address the documented need for tour bus parking², as well as provide a tourism visitor center, geothermal energy, and irrigation for the National Mall turf grass and gardens. Additionally, revenue potential from parking fees and water credits may offer self-financing opportunities that attracts a public-private partnership. However, further study is needed, particularly on the conceptual systems related to phased floodwater intake and evacuation of buses to minimize risk to life safety during a flash flood. Due to the

¹ Reports are listed in Section 4 of the Report

² Need for tour bus parking was identified in the following reports: National Mall and Memorial Parks Tour Bus Study (NPS, 2015), A Review of Access and Circulation on the National Mall in Washington, D.C. (GMU, 2008), District of Columbia Motorcoach Action Plan (DoT, 2011), and Regional Bus Staging, Layover, and Parking Location Study (MWCOG, 2015)

conceptual nature of the overall proposal, feasibility for the Underground was not determined under this current effort. Potential technical feasibility may be evaluated in the future based on key technical review considerations described in Table A.

Table A: Key Technical Review Considerations for Determining Potential Feasibility

Key Technical Review Consideration	Concerns to be Addressed in Future Stages of Development
Can the Underground reduce risk of flooding on Constitution Avenue and in the Federal Triangle area?	Flood risk from a storm of the intensity that flooded the Federal Triangle area in 2006 could be reduced significantly during a flood event by implementation of the Underground. However, further study is needed of the proposed phased floodwater intake system, where water is drawn into compartmentalized parking areas to allow for proper evacuation of vehicles, to demonstrate its capacity to receive and remove floodwater from the study area in a timely manner. This is of particular concern during a flash flood event, when limited warning time may impact the operations of the facility.
Can the Underground be operated and evacuated efficiently to minimize life safety risk during a flash flood event	The primary concern is effective and timely evacuation of any and all persons from the floodable areas of the Underground, that is, the lower bus level. Further study is needed to evaluate various alternatives for the safe evacuation of the Underground, including the Coalition’s proposed automated bus parking system. Forecasting technology and warning time is limited for flash flood events and this may impact decision making triggers for operations of the facility. There are concerns with evacuating a large number of buses out of a confined lower level in a timely manner, and potential backups in the exit ramp of the proposed facility. A detailed operations plan, to include lower level compartment filling and bus evacuation timing, should be developed to identify decision making triggers for the utilization of the facility for flood storage.
Does the structure have enough capacity to store floodwaters for the 200-year flood?	The 2011 Study identified a required 24 million gallons of surface water flood storage for the 200-year storm. The latest concept allows for 30 million gallons of storage according to the Coalition. Further detailed modeling/design may be required.
Can water be conveyed into and out of the facility?	More information is required to analyze the stormwater system upgrades and determine pumping requirements. The project should ensure reliability and redundancy of the pumping system.
Can rainwater / groundwater harvesting cisterns be used for managing floodwaters?	There may be a limited ability to manage flood storage in the cisterns. Further analysis is required to determine whether storage could become available quickly enough to accommodate a subsequent flood. There is concern over water quality within the cistern and if toxic water can be treated for reuse.

Key Technical Review Consideration	Concerns to be Addressed in Future Stages of Development
Are the soil and groundwater conditions suitable for building an underground parking garage in the study area?	Limited soil and groundwater data was provided. A site explorations program is required to determine groundwater and soil conditions.
What is the structural feasibility of constructing an underground storage garage?	All structural loads would have to be designed per governing codes. It is anticipated that the deeper the structure extends, the more difficult the construction would become and more costly to both construct and maintain.
Are there any underground utilities/facilities that could be adversely impacted by the proposed Underground?	There are potential conflicts with the Underground early stage concept layout and surrounding current and future underground facilities and/or utilities. Further investigation of infrastructure and coordination with surrounding entities should be conducted.

Key recommendations from the USACE technical review should be considered in future phases of design. A summary of some of the key recommendations, which are further detailed throughout the report, include:

1. Perform an operational risk analysis to ensure life safety and define trigger points for beginning evacuation of people and vehicles from the structure before and during an event. Due to limited technology, forecasting of severe rain events would continue to be a challenge for the operation of this facility. Separating flood storage and parking area should be considered.
2. Identify any existing and/or proposed underground facilities or utilities in the project area.
3. Further develop a detailed evacuation plan for bus removal during a future flood event.
4. Perform additional analysis to determine the required modifications to the existing stormwater system to allow conveyance of floodwaters into the proposed underground storage system.
5. Evaluate pumping requirements for stormwater and groundwater. Determine pumping station locations of project site.
6. Further refine concept for controlled filling of stormwater into the structure.
7. Further refine concept for emptying structure between storm events, including the usage of rain water/groundwater harvesting cisterns for flood storage.
8. Conduct a study of the reliability of electric power supply during extreme rainfall events.
9. Perform site exploration, including borings and continuous sampling/testing along the alignment to identify heterogeneities that could impact or need special consideration during design and construction. Determine groundwater elevations to support future design work.
10. Determine the requirement for treating the discharged water to better understand the required design and costs associated with the concept.
11. Further refine cost estimates in order to perform detailed economic analysis.
12. Continue to coordinate with stakeholders to determine needs and concerns throughout future iterations of the concept design.

USACE did not review or consider other alternatives to the stormwater flooding problem during this technical review. USACE recommends that further development of the Underground, and of any flood risk management project in the Washington area be part of a collaborative, interagency process for a

comprehensive and resilient solution, as there are many land owners and stakeholders required for implementation of any solution.

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Appendix C: Initial Comments Prior to Charrette

Appendix D: Charrette Notes

Appendix E: National Mall Underground Operational Risk: Protocol and Staging of Floodwaters, Coalition Charrette Response

ACRONYMS:

DC	District of Columbia
FPMS	Flood Plain Management Services
FRM	Flood Risk Management
MEP	Mechanical, Electrical, and Plumbing
NPS	National Park Service
NIP	Notice to Proceed
NWS	National Weather Service
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WWTP	Waste Water Treatment Plant

1.0 BACKGROUND

The District of Columbia (“District”) experienced a severe storm from June 24-26, 2006, that caused extensive flooding within the Federal Triangle area, resulting in millions of dollars in damage. In response to this flood, several Federal and District agencies formed a Federal Triangle Stormwater Drainage Study Working Group (the “Working Group”) to identify measures to reduce the risk and impact of flooding in the future. The Working Group held a series of meetings that investigated the existing sewer system in relation to the Federal Triangle, determined the storm frequencies and durations to be modeled and analyzed, and identified interior rainfall and the Potomac River as causes of flooding. The Working Group developed and evaluated alternatives to reduce the frequency of stormwater (interior) flooding. One of the potential alternatives analyzed by the Working Group was the construction of underground cisterns beneath the National Mall to capture and store rainfall to minimize future flooding. The Working Group concluded that rainfall storage beneath the National Mall is a viable option for reducing the flood risk in the Federal Triangle.

The National Mall Coalition (the “Coalition”), a non-profit organization, took a further look at this potential underground storage option beneath the National Mall by conceptualizing a solution that includes parking. This proposed solution, called the National Mall Underground (the “Underground”), is a multi-purpose car and tour bus parking garage and National Mall visitor center with access to the Smithsonian museums, national monuments, and other cultural attractions. Additional elements include cisterns for irrigation of National Mall turf grass and gardens, and geothermal energy. During heavy rain events, this underground parking structure could function as a stormwater retention reservoir to minimize impacts from stormwater flooding and store water for National Mall irrigation.

In a letter dated May 10, 2017, the Council of the District of Columbia requested support from the U.S. Army Corps of Engineers (USACE) through the Flood Plain Management Services Program (FPMS), for USACE to provide a technical review of the Coalition’s proposal to create an underground reservoir beneath the National Mall that can accommodate a 200-year flood. This effort was funded by the Coalition.

2.0 STUDY AREA

The study area for this effort is the area of Federal Triangle that experiences flooding during heavy to severe rain (Figure 1). The Federal Triangle study area, as established in the 2011 Federal Triangle Stormwater Drainage Study, is in the northwest quadrant of the District of Columbia (DC) and is bounded by 15th St. NW to the west, Madison Dr. NW to the south, 3rd St. NW to the east, and Pennsylvania Ave. NW to the north and northeast. The Federal Triangle area is the home of many prominent buildings owned by the Federal government. The proposed location for the Underground concept is underneath the National Mall, bounded on the east and west by 9th St. NW and 12th St. NW, and on the north and south by Madison Dr. NW and Jefferson Dr. NW. Figure 2 provides a rendering of the proposed location of the Underground.

3.0 PURPOSE

The purpose of this effort was to provide a technical evaluation of the proposed underground rain storage/parking and visitor center option to reduce the interior flooding that currently threatens the Federal Triangle area. USACE reviewed existing documentation prepared by both the public and private sectors to evaluate the technical aspects of this concept plan. An all-day charrette and two webinars were conducted as part of this effort to allow the Coalition to provide clarification on an initial set of comments developed by the team so that a final list of concerns and recommended actions could be developed. Due to the

preliminary level of the concept plans, and lack of detailed engineering analysis and computations, a thorough technical review could not be provided and only general concerns and recommended actions were identified. These recommendations may be used to modify future concept designs. Considering other alternatives was outside of the scope of this effort. The Coalition coordinated with various DC and Federal agencies in developing the Underground concept. However, it is likely that stakeholders would want to compare various flood risk management solutions before supporting a final plan.

Figure 1: Map of Study Area

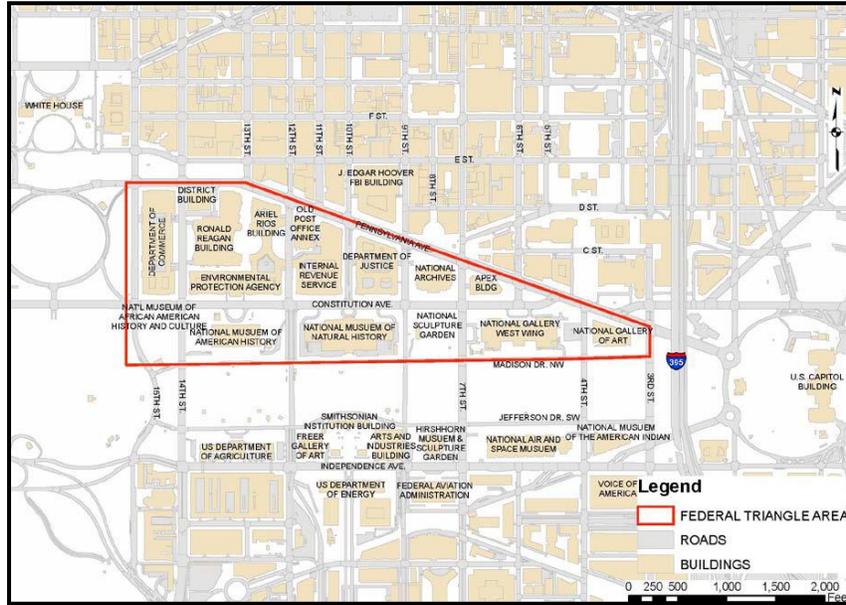


Figure 2: Location of Underground Garage/ Flood Storage Structure



(Source: Arthur Cotton Moore)³

³ Alternative reviewed for this technical review only allows for flooding in the lowest level of the parking garage.

4.0 METHODOLOGY

USACE organized a national team of experts from various disciplines to conduct a technical review of documents⁴ provided by the Coalition, including:

- Flood Mitigation and Prevention Draft Study, GSA Federal Triangle Buildings Washington, DC (GSA, 2007)
- A Review of Access and Circulation on the National Mall in Washington, D.C. (GMU, 2008)
- District of Columbia Motorcoach Action Plan (DoT, 2011)
- Federal Triangle Stormwater Drainage Study (DC Water, 2011)
- National Mall Parking Garage Feasibility Study with Parking Memorandum, Mall Option Exhibits, and Garage Option B-1 Profile (Dewberry, 2011)
- National Mall & Memorial Parks Reconstruct Turf and Soil on the National Mall, Volumes 1 & 2 (NPS, 2011)
- Preliminary Projections of Parking Income and Expense Excel Workbook, Version 1 (Colonial Parking, 2013)
- Design/Bid/Build Schedule and Project Budgets (Clark Construction, 2013-2014)
- Draft National Mall Underground Financial Analysis (PES, 2014)
- National Mall & Memorial Parks Install Irrigation, Drainage, Water Collection System and Relandscape The Mall 7th Street to 14th Street/ Jefferson to Madison Drive, volume 3 (NPS, 2014)
- National Mall Underground Parking Demand Study, Technical Memorandum (Gorove/Slade, 2014)
- National Mall Underground- Water Budget Technical Report (Dewberry, 2014)
- National Mall and Memorial Parks Tour Bus Study (NPS, 2015)
- National Mall Coalition- National Mall Underground Project Pre-Development Period Budget and Supplemental Attachments (Pickman Borod, 2015)
- Regional Bus Staging, Layover, and Parking Location Study (MWCOG, 2015)
- South Mall Campus Master Plan Draft Environmental Impact Statement (Smithsonian, 2017)
- Arthur Cotton Moore NMU Concepts Drawings and Schematics (2013-2018)

The concept that was provided by the Coalition for review includes a multi-purpose parking garage with a floodable lower level. The structure would be placed underground and would provide car parking in the upper level and bus parking in the lower level. During storm events, the lowest level of the structure would act as a water storage vault and bus drivers would have to evacuate buses out of the garage structure. Figure 3 shows a concept rendering of the proposed underground parking garage/flood storage structure and its car entrance from the 12th St. NW tunnel and tour bus entrance and exit via a ramp between the Smithsonian Arts & Industries Building and Hirshhorn Museum; cars would also exit via this ramp. During the course of the technical review, the Coalition provided additional modifications to the design concept with regards to floodwater intake and evacuation procedures. The latest Underground concept design includes a segmented water intake system, which would allow water to enter the lower levels of the garage in stages in order to allow for proper bus evacuation times. Figure 4 shows a concept rendering of the staged filling of floodwaters.

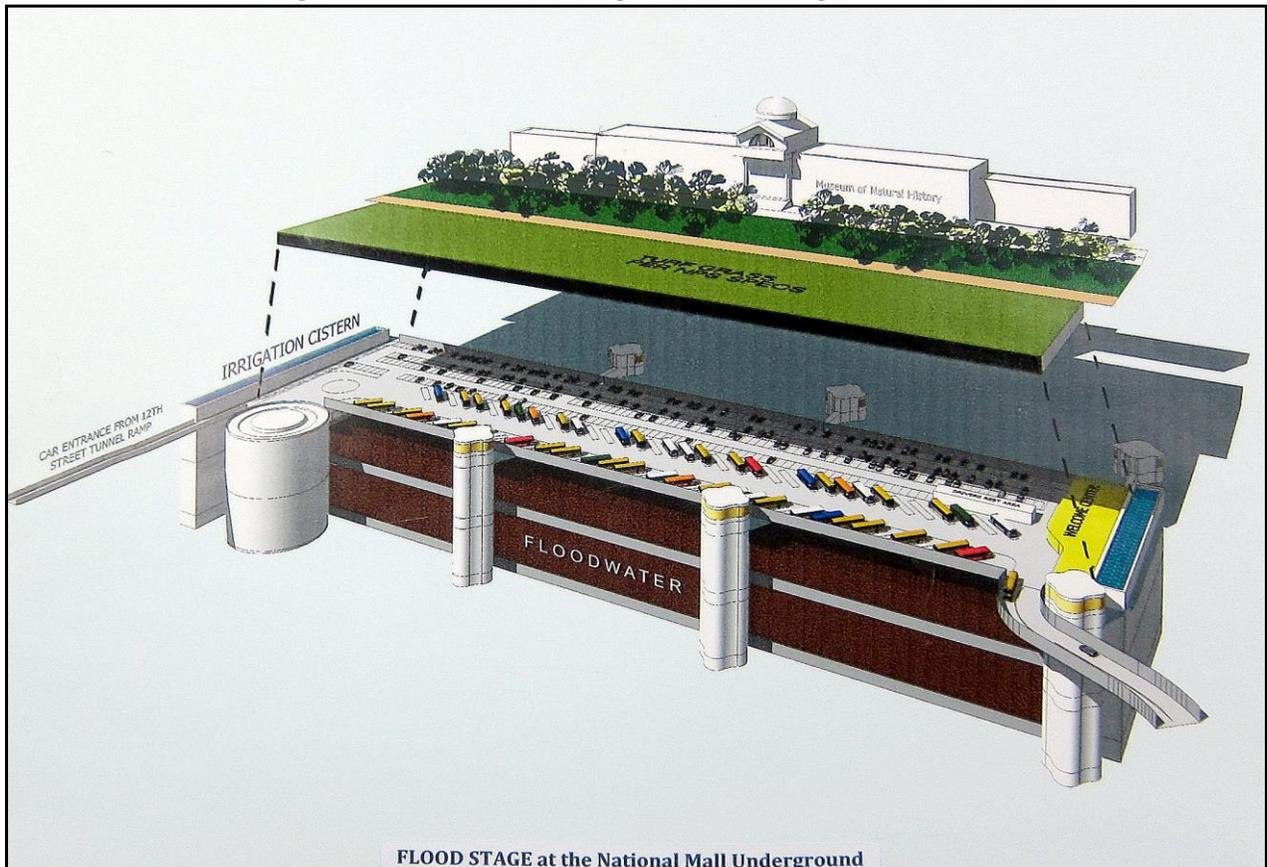
The USACE technical review team consisted of two hydrologists, one structural engineer, two civil engineers, two planners, one construction specialist, and one mechanical engineer. The team coordinated with the Coalition at the onset of the project to develop a list of charge questions related to each discipline. These charge questions, provided in Appendix B, were developed to help guide the team during the

⁴ A summary table of the reviewed documents is provided in Appendix A.

technical review process due to the conceptual nature of the proposed project. The team developed an initial set of review comments, provided in Appendix C, that identified initial concerns and recommendations based on data provided by the Coalition. Then, an all-day charrette, a face-to-face meeting between the review team, Coalition members, and a Coalition engineering consultant, was conducted to provide the Coalition an opportunity to clarify various questions and comments provided by the team. These conversations and clarifications were reflected in the final set of comments provided in this report.

The final set of comments provides a clear set of concerns and recommendations with respect to the technical aspects of the proposed underground rain storage system. These comments are meant to assist the Coalition in making future decisions regarding further study and design of their proposed solution.

Figure 3: Section of Garage/Flood Storage Structure

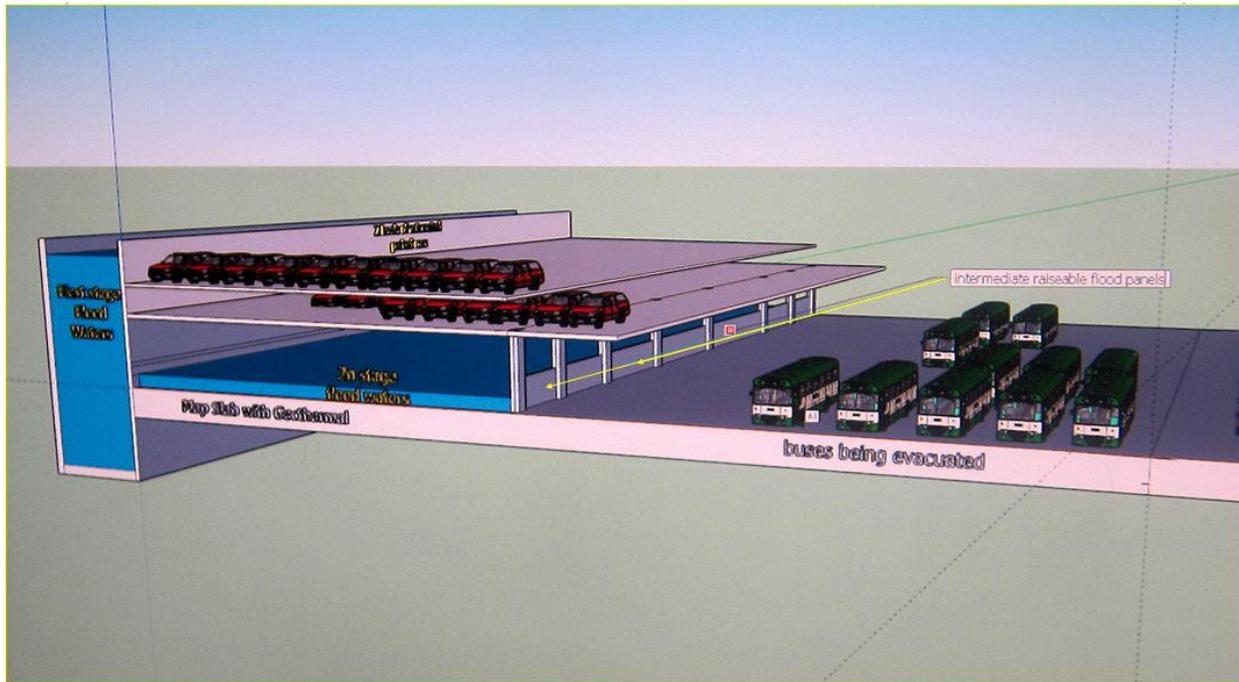


FLOOD STAGE at the National Mall Underground

(Source: National Mall Coalition)⁵

⁵ Alternative reviewed for this technical review only allows for flooding in the lowest level of the parking garage.

Figure 4: Rendering of Staged Filling of the Underground



(Source: National Mall Coalition)

5.0 RESULTS OF TECHNICAL REVIEW

Summary of Key Issues

Based on review of the documentation provided by the Coalition throughout the technical review, the discipline experts determined that the flood risk from a storm of the intensity that flooded the Federal Triangle area in 2006 could potentially be reduced significantly through implementation of the Underground. According to the Coalition, the latest Underground concept allows for 30 million gallons of storage, which would satisfy the required 24 million gallons of surface water flood storage identified in the 2011 study. However, further study is needed of the proposed phased floodwater intake system, where water is drawn into cisterns and then compartmentalized parking areas to allow for proper evacuation of vehicles, to demonstrate its capacity to receive and remove floodwater from the study area in a timely manner. This is of particular concern during a flash flood event, when limited warning time and forecasting capabilities may impact decision making triggers for operations of the facility. Further study is also needed to evaluate various alternatives for the safe evacuation of the Underground, including the Coalition's proposed automated bus parking system. The concept should be designed to ensure the effective and timely evacuation of any and all persons from the floodable lower bus level.

Additional concerns to be addressed in future stages of development include:

- More information is required to analyze the stormwater system upgrades and determine pumping requirements. The project should ensure reliability and redundancy of the pumping system.
- There may be a limited ability to manage flood storage in the cisterns. Further analysis is required to determine whether storage could become available quickly enough to accommodate a subsequent flood. There is concern over water quality within the cistern and if toxic water can be treated for reuse.

- Limited soil and groundwater data was provided. A site explorations program is required to determine groundwater and soil conditions.
- All structural loads would have to be designed per governing codes. It is anticipated that the deeper the structure extends, the more difficult the construction would become and more costly to both construct and maintain.
- There are potential conflicts with the Underground early stage concept layout and surrounding current and future underground facilities and/or utilities. Further investigation of infrastructure and coordination with surrounding entities should be conducted.

The following subsections document the specific topics identified by each of the various discipline experts. Each section describes the pre-charrette comments, responses from the charrette (when applicable), residual concerns, and a set of recommendations, which could be used by the Coalition going forward. Due to the conceptual nature of the proposal, further study would be needed on various components of the Underground in order to evaluate its overall technical feasibility.

5.1 OPERATIONAL RISK, EVACUATION, AND LIFE SAFETY

Pre- Charrette Comment #1:

One of the biggest concerns with this concept is the ability to store floodwaters during a storm event while evacuating all vehicles from the flooded levels of the structure and keeping people safe. In order to closely analyze this concern, it is recommended that an operational risks assessment be conducted on the proposed concept. All time lines, procedures, and personnel required for operation could be analyzed in depth and run through Monte Carlo simulations. Report would include: defining trigger points when operations need to begin; defining minimum and maximum time elements for each operational step; worst case scenarios (middle of the night on a holiday weekend or perhaps street traffic jams backing up the ability for vehicles to leave out exit ramps); defining required work crews to operate the system; etc.

Pre- Charrette Comment #2:

The 2006 flood and other flash floods that would require the proposed underground storage system are difficult and unreliable to predict.

Pre- Charrette Comment #3:

There could be events through the years that hit the trigger point requiring evacuation of vehicles but may not end up large enough to require the underground structure to be filled with any stormwater. These trigger events, which cause evacuations yet no filling of the structure, must not sway future operation actions to execute at the set trigger point.

Pre- Charrette Comment #4:

Must have controlled flow of stormwater into the parking area. Would have to have an evacuation procedure and method to prevent human or unauthorized entry during stormwater retention. There are potential life safety concerns if reliable evacuation and preventative re-entry processes cannot be established.

Pre- Charrette Comment #5:

Filling of stormwater into the underground structure would need to be controlled, either by means of gates or a pump system to prevent premature flooding of the structure before all vehicles are evacuated and to prevent overfilling the structure if the top underground level is to remain dry.

Responses from Charrette:

Based on discussions during the charrette, the Coalition Project Architect, Arthur Cotton Moore, provided additional information about procedures for a staged intake of floodwater into the floodable bus level. An emergency alert system coordinated with the National Weather Service

(NWS) would identify weather events that might cause heavy rainfall and stormwater flooding in the Federal Triangle Area. The lower bus level/stormwater detention area would be closed 12-24 hours before anticipated heavy rain and flooding. There is acknowledgment that there would likely be various false triggers due to uncertainty. The structure would fill in stages starting with an underground cistern at the west end of the garage and then sequential filling of five compartments separated by raisable aluminum floodwalls to allow for bus evacuation. Details on the staged filling approach are provided in Appendix E.

Concerns:

- Ability to execute evacuations and operation of stormwater detention within limited time constraints.
- Current early stage concept lacks detailed operational procedures, sequence and timing of operations, etc.
- Traditional methods that define a trigger point during flood events are challenging for use in this concept given how small the watershed is for the Federal Triangle and National Mall areas and the flashy nature of the flooding.
- Concern with operators/owners of the facility deviating from prescribed trigger point. There could be many precipitation events in the future that hit the trigger point causing the operational plan to be executed and evacuation of the structure to occur but ultimately end up being non-events from the standpoint of not utilizing the detention of any stormwater within the underground structure; closures for non-events should not influence future decisions to not close with similar forecasts.
- Concern as to how stormwater would be controlled when filling the lower levels of the multi-purpose structure. Even with the additional information provided by the Coalition post-charrette, there is concern associated with the complexities and operational requirements for a compartmentalized system. It is still believed that the proposed filling-evacuation system lends itself to management and maintenance complications.
- A correlation between the time to fill the rainwater harvesting cistern and that to evacuate the first flooding compartment would have to be performed.
- In the case of an emergency or system failure within the lower levels of the parking facility, stormwater prevented from entering the facility during a significant flooding event may have to be diverted away from the structure somehow and allowed to remain on the surface to flow overland and back into the local storm drain system.
- Maintaining safety elements associated with an underground parking garage at all times to include life, vehicles, and cargo that would be present within the lower levels of the underground structure may be challenging.
- The updated proposal to create five compartmentalized areas within the structure with hinged panels would make the project become complex, very quickly. It would require multiple filling controls and raise the need for operational personnel that are only needed when a flood event occurs. There is a risk that the compartmentalized concept would leave no margin for error or time to adjust for failures and with more components, the risks for failures in the system increase, requiring redundancies in the system.

Recommendations:

- Develop an operational risks assessment on the proposed concept. Assessment would contain a detailed breakdown of all operational sequential steps from start to finish, including well documented trigger points. Each step element within the operational sequence would be examined to capture minimum and maximum timelines given best case scenarios, worse case scenarios, and probabilities of timelines in between.

- A detailed operational risk assessment could serve as a useful design tool to determine what is reasonable and acceptable from a risk standpoint. Recommend risks for successful operation be set to address 95% or more of the identified risk. Tradeoffs on the amount of time available to execute versus the number of vehicles the structure can safely hold could be analyzed to help define the design concept. This assessment could be used to define all variables such as number of stalls, the number of lift systems, number of exit lanes, parking policy that sets time limits, etc.
- A trigger point would need to be set early enough to ensure life safety to the fullest extent possible and minimize risks to loss of vehicles and contents.
- As discussed during the charrette, operation should consider limiting or prohibiting parking within the storm detention levels of the structure during non-operational hours. Consideration should be given for requiring detention levels of the structure to be emptied out every night or have restricted parking hours to prevent any vehicle from being there long term in the case of an event requiring evacuation.
- Per discussions from the charrette, closure of the lower bus level in advance, based on NWS predictions would likely be the best option to ensure the bottom level is vacant, as opposed to trying to evacuate vehicles when a flood is imminent. However, setting response activation based on this type of predicted forecast information could be challenging as in many instances, forecasted data differs from that of actual events. This may lead to false triggers and associated parking level closures.
- Concept should consider around-the-clock monitoring to identify when a response trigger is hit. There would be a need for a year-round and 24-hour per day monitoring system.
- Recommend that filling of the structure be controlled by slide gates to have positive closures on all filling culverts coming into the proposed structure.
- Consider designing valve/gate system to control water entry with a lockout-tag out system to prevent unintended fillings.
- Define how stormwater would be controlled within the structure to prevent it from overflowing to prevent flooding of the upper underground level. This may include closing back down the storm slide gates to prevent any further filling of the structure and having redundancy in the system in the case of the gates failing.
- Complexities of equipment and operations should be minimized to the furthest extent possible.

Pre-Charrette Comment #6:

Concerns with buses parking on a level that would be flooded during a high flood event. When and who determines when buses can and cannot park there? There is limited flood warning time for this type of interior flooding. This is a major life safety issue to have buses and bus drivers in an area that can be submerged. Would it be closed to buses if heavy rain is predicted? If significant rain starts during the day and it must close, how are bus drivers notified?

Pre-Charrette Comment #7:

How much time would it take the buses to evacuate if heavy rain starts during the day? Concerned with bus drivers being trapped in the garage.

Responses from Charrette:

Based on discussions during the charrette, Project Architect Moore provided additional information. In the case of unanticipated flash-flooding, emergency notification would be sent via text, Twitter, and other means to bus drivers and others of the need to evacuate the facility, while staged intake of floodwater takes place, as described in Appendix E. Additionally, there would be a dormitory where bus drivers could be close to the buses in case of emergency. Bus drivers would

be mandated, by contract, to stay near their vehicles. Bus drivers would be provided a dormitory, where they could sleep, eat, and shower.

Concern:

- Concern remains over life safety threats due to uncertainty of forecasting severe flood events.
- Concern remains over who the decision making body would be for determining closures.
- Concern remains over whether efficiency during a flash flood can be guaranteed due to the introduction of human error associated with buses being manually driven out of the flooded level.
- The evacuation of a large quantity of vehicles given a relatively short notice would be challenging and would require sensitive triggers for parking outage to be reliable. The damage to vehicles that could not reasonably be evacuated should be deducted from benefits calculated for the implementation of the project.

Recommendations:

- Develop a detailed evacuation plan for the lower levels that are to serve as a stormwater detention basin as part of the operational risk assessment.
- Clearly delineate (in as much detail as possible for a concept phase) who the responsible parties would be for decision making and evacuations. This may change upon implementation of the final concept, however it would be useful to help gage level of complexity for coordination (linked to operational risk assessment) and required resourcing.
- Provide an evacuation simulation to better depict evacuation procedures. Bus evacuation times need to be identified in order to provide a better estimates for clearing of the entire flooded level.

Pre-Charrette Comment #8:

Where would buses park on days that the facility is closed if they had planned to park there?

Responses from Charrette:

Based on discussions during the charrette, the Coalition stated that closure of the garage during storm events would result in street parking and idle buses along the National Mall, similar to the status quo. However, it was also recognized that there is a possibility that enforcement of current parking regulations would likely increase due to the availability of the new garage parking options. The Coalition also stated that it is considering identifying alternative locations for buses to park in the event of garage closures.

Concern:

- With the potential for a large number of false triggers, closure of the facility may cause transportation issues for pre-planned bus and vehicle tourism. This may prove a large disincentive for local stakeholders.

Recommendation:

- Consider identifying land which could provide auxiliary/emergency parking during events to offset lost spaces from the flooded third floor. Potentially look across the Potomac River in Virginia if land is not available closer to the National Mall. Tourist may then be shuttled to the Mall area from the auxiliary lots.

5.2 STORMWATER INFRASTRUCTURE UPGRADE

Pre- Charrette Comment #1:

There is a lack of documentation on the modification of the existing stormwater infrastructure required to effectively collect and convey stormwater into the underground storage system.

Responses from Charrette:

Based on discussions during the charrette, the Coalition recognizes that stormwater infrastructure north of the system would require substantial upgrades. However, the Coalition feels that this should be covered by other stakeholders. There was overall consensus that it would be highly beneficial to see DC Water's modeling of the overall system.

Concerns:

- If the required modifications of the existing system required to convey stormwater to the underground collection system are not taken, the intended flood risk reduction may not be achieved.
- The requirements for modification of the existing system must be understood to identify potential technical limitations and reasonable cost estimates.
- Implementation of the stormwater collection system upgrades may lead to impacts to surrounding buildings and streets.

Recommendations:

- Additional analysis is necessary to determine the required modifications to the existing stormwater system to allow conveyance of floodwaters into the proposed underground storage system. This would include the identification of existing system upgrades and installation of new components (e.g. pipes, intakes, curbs, pumps).
- It may be possible to convey flood flows at low levels, at curb heights, through the streets in lieu of replacing undersized storm sewer pipes within the area of concern. Gravity flow of flood flows through the streets might be a consideration to look into if there is an existing street level low point closer to the proposed detention structure. This may help reduce the amount of underground storm pipes that would have to be upsized.

5.3 GENERAL PUMPING

Pre- Charrette Comment #1:

Ensure that the design includes adequate space allowance for pumping, gate equipment and controls.

Pre- Charrette Comment #2:

To adequately evaluate pumping requirements, elevations of parking garage and storm sewers need to be estimated.

Pre-Charrette Comment #3:

The need for groundwater pumping should be evaluated as well as pumping of water from other sources such as wash down water. This may require additional smaller pumps than the stormwater pumps.

Responses from Charrette:

The Coalition acknowledged that pumping was not included in the designs and costs.

Concerns:

- Conceptual drawings do not appear to allocate space for pumps, gate operating equipment and associated operating equipment and controls.

- Elevation information is necessary to determine pumping requirements. Designs have not been developed to date.
- Allowing adequate space for pumps and water control equipment could reduce the space available for parking.
- Stormwater pumps would likely be too high of volume for pumping water from other sources and pump cycle time too short when pumping these other lower volume quantities.

Recommendations:

- It was clear during the charrette that the conceptual level of design of the alternatives did not provide for physical design details for the pumping system. This seems appropriate for this design level, but the comment is made to ensure that sufficient cost contingencies are included and that available space for parking is not overestimated to allow for inclusion of pumping facilities.
- Set aside an adequately sized area for pumping equipment, controls, and water conveyance equipment.
- Conduct detailed analysis of stormwater system and storage facility to determine pumping requirements.
- If mechanical parking equipment is used, ensure that sufficient space is set aside for that equipment as well.
- Evaluate pumping needs for stormwater and other sources separately.

5.4 EMPTYING OF STRUCTURE

Pre- Charrette Comment #1:

Gravity drainage for this structure would likely not be permissible due to its depth. Pumps, likely mounted near surface elevation, would be required to remove normal and flood event rain water from the structure. Measures would have to be made to minimize any exhaust and noise created.

Concerns:

- Depth of structure would likely be too deep to empty any detained water by gravity flow.
- The concept plans do not currently outline the process for removing normal and flood event rain water from the structure.

Recommendations:

- Develop concept to define emptying system of detained stormwater. System would likely have to be a submerged pumping system capable of handling gritty materials.
- Include pumping and ventilation systems in the design of the facility.
- The drawdown discharge capacity of the pump station should be evaluated to ensure that the intended level of flood damage reduction is provided.

5.5 RAINWATER HARVESTING CISTERNS

Pre- Charrette Comment #1:

Based on the reviewed information, rainwater harvesting for preliminary flood storage would be limited to smaller events. The major events are a challenge for two reasons:

- 1.) *The water would need to be immediately pumped to be available for subsequent periods of intense rainfall within that event and future events, and*
- 2.) *The major events would likely flood numerous vehicles and would therefore be contaminated with volatile organic compounds.*

Pre- Charrette Comment #2:

The potential for rainwater harvesting seems to be technically feasible based on the information provided; although the allocated storage for harvesting should not be considered in the flood storage available unless a rapid drawdown strategy is developed and followed.

Responses from Charrette:

Based on discussions during the charrette, Project Architect Moore proposed concept design modifications to allow stormwater to be diverted first to the larger ground water cistern, which is designed both to accommodate groundwater and to receive early substantial rainfall. Check valves would ensure that this cistern is never more than half full of groundwater. Using this cistern as the first stage response to flooding would allow time for buses to be removed from the first of the five compartments in the lower level of the garage facility. The Coalition also acknowledged that the stored floodwater would need to be treated for contaminated volatile organic compounds. Water could be cleaned to levels of water quality comparable to the Potomac through the potential acquisition of a piece of land and creation of small mound to house linear wetlands to clean water. Water would not be directly pumped into the tidal basin.

Concerns:

- Functionality of rain harvesting cisterns during flood events and after flood events.
- If interconnected with the larger stormwater detention structure, concern with cisterns being full or having lost capacity during flood events. If flood storage is utilized prior to the occurrence of the design storm, for harvesting or antecedent storm event, then the intended level of flood protection may not be provided.
- Environmental concerns with water quality for stormwater that is detained within the structure being re-used or pumped out of the system.

Recommendations:

- Concept should include detailed operational and timing criteria of these dual purpose features.
 - If interconnected, define how controls, operational plans, and design storage capacities account for management and operations concerns.
- Consider physically separating the storage intended for rainwater harvesting from the flood storage to ensure that the intended storage is available when needed and minimize contamination and cleanup of the parking area.

5.6 RELIABILITY AND REDUNDANCY

Pre-Charrette Comment #1:

An evaluation of the reliability of electric power would need to be performed and possibly backup power supplied for pumping and other emergency loads included.

Responses from Charrette:

During the charrette, Project Architect Moore stated that the Coalition had not included pumping into the design costs, but recognized that there would likely be the need for standby generators to power pumps.

Concerns:

- A loss of electrical power would halt evacuation of the lower level if a mechanical system was used and no backup system is provided.

- A loss of electrical power would stop any pumping either into or out of the structure or actuation of control gates if no backup system is provided.

Recommendations:

- Conduct a study of the reliability of the electric power supply during extreme rainfall events.
- Provide for backup power if warranted and set aside space for this equipment.
- During the charrette, it was recognized that there would be a need for standby generators to power the pumps. At this conceptual level of design it is likely not necessary to size those, but the comment is made to ensure that appropriate cost contingency and space allocation is provided for.

Pre-Charrette Comment #2:

System components should take into account redundancy and have back up plans if primary flood risk management components fail or break.

Pre-Charrette Comment #3:

Recommend a high level of redundancy for stormwater pumps, water control gates, and mechanical parking system.

Concerns:

- A single component malfunction should not be allowed to prevent successful evacuation of the lower level of the garage or the pumping of the water in or out.
- Longevity of concept features that are subject to corrosion due to exposure to water and/or humid conditions such as steel members.
- Longevity of mechanical equipment and electrical components.
- Ability for the system to execute operation plan should individual components happen to fail.

Recommendations:

- Concept should seek to simplify components as much as possible. More complex systems that involve a larger amount of moving parts and controls have greater operational maintenance, costs, and risk of failure.
- If the proposed concept includes potentially having a mechanical storage garage on the lower levels, this would be a very critical system that would need to have redundancies built into it such as emergency power generation given power outages are often associated with storms that produce heavy precipitation events.
- Provide sufficient redundancy in pumps, water control gates/valves, and controls.
- If used, provide redundancy in the mechanical parking system to ensure the ability to evacuate the garage even with individual component malfunction.

Pre-Charrette Comment #4:

All equipment and features within the flooding levels of the structure would need to be designed for submergence. This may include lights, motors, elevators, electrical lines, mechanical equipment, etc...

Responses from Charrette:

Based on discussions during the charrette, the Coalition acknowledged that equipment and features within the lower flooding levels would have to be designed for submergence. Additionally, a new concept is being explored that would include an automated parking system in the lower level. The Coalition stated that it is currently working with a private parking company licensed to develop and utilize a Navy-tested automated system that could be adapted for bus parking in the lower level and reduce the risk to humans where floodwaters would be detained. However, the concept is still in its early phases and the Coalition requested that USACE focus on the original concept provided.

Concerns:

- Concept components on the lower levels would be subject to submergence during each flood event.
- Life safety and property damage concern if high degree of automation used. Malfunction of systems cause unforeseen issues with pumping, premature flooding of the garage, or evacuation of the garage.

Recommendations:

- Provide sufficient manual overrides and manning of the facility, to include the automated parking apparatus as well as the valves, gates, and components to control intake of floodwaters, to ensure that it can be operated in the case of failure of automation components.

5.7 STORAGE CAPACITY BASED ON MODELING

Pre- Charrette Comment #1:

The required underground storage to eliminate stormwater flooding related to a 200-year rainfall event is not well documented and should be confirmed prior to implementation.

Pre- Charrette Comment #2:

The stormwater system that contributes drainage to the Federal Triangle is complex. The description of the hydrologic modeling suggests that it is only calibrated to a single event (i.e. 2006), this is very limiting for a sophisticated model with many parameters, complex geometry, and multiple boundary conditions.

Responses from Charrette:

Based on discussions during the charrette, the Coalition stated that the 2011 Federal Triangle Study requires the retention of 24 million gallons of floodwaters for the 200-year storm event. According to the current original concept designs provided to USACE, the underground storage system would have up to 28 million gallons of capacity. Additional information provided post-charrette (Appendix E) shows that the system may be able to hold up to 30 million gallons.

Concerns:

- A 6-hour rainfall duration was used in determining the design storm event. Although this should be significantly long to evaluate peak discharges; it does not adequately account for longer duration storms with intense bursts of heavy rainfall or consecutive rainfall events.
- Based on the description and calibration of the hydrologic model, there is low confidence in the ability to predict the runoff conveyed to the Federal Triangle during a design storm event.
- The most recent reported storage volume of 30-million gallons, is approximately 92 acre-feet; this is a relatively small volume for a drainage area of 5.8 square miles (approx. 0.3 inch of rainfall excess). There is concern that the storage volume may not be sufficient for a flooding scenario similar to the 2006 flooding where a large area was flooded with several feet of depth; although a detailed investigation into the required storage was not part of this review.

Recommendations:

- Evaluate a variety of storm scenarios (durations and temporal patterns), including multiple systems, to determine the required storage allocation to provide the intended level of flood damage reduction.
- Verify that the model is appropriate for the design of both the existing system upgrades and the required storage to eliminate flooding of the Federal Triangle from a 200-year storm event.
- Compile a flood history of the flooding of the Federal Triangle to provide an empirical means to evaluate the benefit versus cost associated with the proposed plan for underground storage. This may also be beneficial in understanding the capacity of the existing system and the components that would require upgrade.

- An isolated stormwater storage system should be investigated. This system would allow for the pump machinery and electrical systems to be located in the current parking facility; but the majority of the flood storage would be located in low cost vessels adjacent to the proposed underground facility.

5.8 GEOTECHNICAL SITE AND GROUNDWATER DATA

Pre- Charrette Comment #1:

Additional review of existing data and reports concerning regional and local hydrogeology could be advantageous with regards to project design and cost estimation and construction. For example, the United States Geological Survey (USGS) has some existing reports concerning groundwater of the area, and these reports contain many references, which also concern groundwater information that would be generally helpful. Also, research and obtainment of any existing data concerning groundwater-related design and possible difficulties during construction of nearby structures should be possible and advantageous.

Pre- Charrette Comment #2:

Some site-specific data likely exists and some engineering evaluations have previously been performed which this review is not aware of given its scope and materials provided. For example, the 2011 Feasibility Study by Dewberry stated conceptual plans for possible underground garages were based on " cursory engineering evaluations related to site, structural, and geotechnical considerations..."

Responses from Charrette:

Based on discussions during the charrette, the Coalition concurred with the need to obtain more information regarding surrounding structures and their design, construction, and performance history. Useful information likely exists in the public domain but has not yet been collected. The Coalition expressed interest in USACE supporting the effort to obtain such information, however this was not a task for this technical review.

Concerns:

- Without obtainment and review of valuable information from nearby case studies regarding construction and subsequent performance approaches and issues, the likelihood of achieving an optimized design and successful construction would be reduced. The time invested to obtain and review this information to the extent it exists would likely payoff by helping better define and advance design and construction concepts for the project, and in reducing cost uncertainty.

Recommendations:

- Compile all engineering evaluation details and data to date, which may exist but which may not be included in the current project files record. For example, contractor and reviewer inputs could be improved with awareness of more information and it could reduce the potential for any future replication of efforts or data.

Pre- Charrette Comment #3:

An exploration program for the proposed construction area is intended to be conducted (per the cost estimate provided as material for this review). Soil sequences resulting from the fluctuation of sea level and glacial meltwater inflow are often highly variable requiring frequent data to characterize.

Responses from Charrette:

The Coalition indicated during the charrette that conventional sheet piling supported excavation was anticipated for the project. It was discussed that other approaches may be considered, and the Coalition was interested to review additional information. As part of future design efforts following

the obtainment of additional site specific information through research and exploration, optimal construction approaches will be further considered.

Concerns:

- The estimated amount for exploration and testing appears low. Engineering parameters needed for further evaluation of concepts and ultimately design do not currently exist for the project area.
- The anticipated inflow for a deep excavation may be difficult to reliably estimate at this time without more data. While the proposed project concept can most likely be built, the manner in which this could best occur and what the structure itself would ultimately be are difficult to define with certainty at this point.

Recommendations:

- Future borings and continuous sampling/testing should be performed along the alignment to identify heterogeneities that could impact or need special consideration during design and construction. Disturbed and undisturbed sampling and testing should be carefully planned and performed to obtain parameters required for construction and structure design computations such as bearing, heave/uplift, settlement, sliding (into excavation e.g.), lateral loading, etc. The exploration/testing program should further define groundwater in terms of perched and year-round static water level variations, and pump-testing utilizing new monitoring wells could provide important bulk permeability information relevant to construction dewatering needs estimation. This data would also help the design of drainage and waterproofing needs for the proposed structure. These data and perhaps preparation of a Geotechnical Baseline Report would serve to reduce uncertainty and could ultimately be a good return on investment by leading to lower cost proposals by bidders. Further relevant case studies would also be important with new exploration/testing data.

5.9 WATER QUALITY MANAGEMENT

Pre-Charrette Comment #1:

Water discharged from the parking garage may need to be treated before release to the waterways.

Responses from Charrette:

During the charrette, Project Architect Moore stated that the Coalition is currently exploring the potential for controlled release into Blue Plains Waste Water Treatment Plant (WWTP). There is also the potential for acquiring a piece of land and creating a small mound to house linear wetlands to clean discharged waters from the system. Water could be cleaned to levels of water quality comparable to the Potomac River.

Concerns:

- Due to the conceptual nature of the current plans, water treatment requirements were not evaluated for discharged water from the system. Without knowledge of these requirements it is difficult to determine where water retained in the parking garage should be pumped.
- If water must be pumped to the water treatment plant, this would likely increase cost over a plan that discharges the water to the tidal basin.

Recommendations:

- Determine the requirement for treating the discharged water to better understand the required design and costs associated with the concept.

- Determine and document what the water quality discharge requirements would be for the detained stormwater within the proposed structure, based on District regulations. Address and document any additional treatment and/or monitoring requirements that may be required of the proposed concept.
- Document permit requirements and if appropriate agencies determine no concerns for detained stormwater discharges.

Pre- Charrette Comment #2:

Silt, leaves, trash, oils, and other contaminants would be in the floodwaters collected and stored in the lower level(s).

Responses from Charrette:

Based on discussions during the charrette, Project Architect Moore stated that there are current cleanup efforts at Washington Harbor that could be used as a model for the cleanup effort in the lower levels of the detention basin of the garage. At Washington Harbor, river water from the Potomac carries large amounts of sediment, which would not be as large of a concern for the Federal Triangle study area. However, sediment in this case would likely contain more toxic materials/chemicals from urban runoff (motor oil, leaves, gasoline, trash, sewage, etc.).

Concerns:

- These waters would have to be pumped to a facility to be treated prior to introduction back into the waterways system.
- Trash racks would have to be used to prevent damage to pumps.
- Trash rack and retention level(s) would require cleaning after each event.

Recommendations:

- Include detailed water treatment system and maintenance systems in the facility design.
- Based on the charrette comment, established after-event cleaning effort costs at Washington Harbor may potentially be scaled and applied to Underground when developing cost estimates.

5.10 SECURITY

Pre- Charrette Comment #1:

This may be a terrorist target due to the confined space, crowds, and transport ability of explosives. Security would likely have to be high, especially if the upper level would house gathering areas.

Responses from Charrette:

Based on discussions during the charrette, Project Architect Moore stated that buses, cars, and pedestrians would go into a screening area prior to entering the garage. This would also be where passengers would exit the buses.

Concerns:

- Every vehicle may have to be searched with the current facility layout, affecting daily operations.
- Directly above the underground parking is the most dangerous with regards to potential underground explosives.

Recommendations:

- Recommend that, if floodwater storage and parking are combined into one facility (as currently designed), water storage would be in the lower level and parking in the upper level with an automated parking system and detailed inspection programs.

- Underground parking may be safer when combined with a 100% automated system with no passenger entry.

5.11 STRUCTURAL ADEQUACY

Pre- Charrette Comment #1:

The structure should be supported, or fit over the footprint of the lowest level.

Responses from Charrette:

Based on discussions during the charrette, Project Architect Moore stated that the Coalition is considering conventional sheet piling. According to the Coalition engineering consultant, this would prevent uplift. Another option would be a thick mat slab to weigh down the structure. The potential design of a super structure was also discussed. This would include pre-cast bearing walls and would utilize unreinforced concrete with saturated elements, similar to the McMillan Plant. There is also the potential for a steel frame structure, if an automated system is desired.

Concerns:

- Movement of the structure during filling of the lower level with floodwaters is possible.
- Concern with adequacy of a sheet piling approach to be ideal, and its ability to prevent uplift as a stand-alone measure. This would require re-evaluation once better data becomes available and design work progresses.
- Depending on the groundwater levels, the structure can experience large uplift forces and/or large floodwater downward loads.
- If relatively large movements occur, any parts of the structure protruding laterally from the foundation could experience large stresses.

Recommendations:

- Thoroughly investigate and design for all credible load cases.
- With consideration to the charrette comments, the above recommendation is still valid. Most, if not all, normal design loads can be resisted through basic engineering principles. Typically, however, the larger the load, the higher the cost to design and construct the structure.

5.12 REQUIREMENTS FOR CONSTRUCTION IN STUDY AREA

Pre- Charrette Comment #1:

Is the Coalition aware of what exists under the National Mall in this area? Are there current or future underground utilities and/or facilities that would affect the project?

Pre- Charrette Comment #2:

Potential conflicts with 2017 Smithsonian Institution, South Mall Campus Master Plan for the alternatives that call for underground expansion.

Responses from Charrette:

Based on discussions during the charrette, the Coalition acknowledged that, while Dewberry had performed a feasibility study to determine site locations for the Underground, further site exploration is required to confirm that the area is clear of sensitive underground utilities/facilities. The Coalition also acknowledged that continued coordination with surrounding entities, including the Smithsonian, would be required to ensure the project does not adversely impact other planned facilities.

Concerns:

- There is currently limited knowledge of facilities or infrastructure that may present a limitation for placement of the Underground concept.

Recommendations:

- Recommend one of the first steps prior to advancing concept designs being to ensure that this area is clear of current or future underground facilities and utilities. This would include coordination with adjacent stakeholders, utility companies, and land/property owners.
- Recommend utility survey. Contact Miss Utility and third party locator. Miss Utility may not operate on National Park Service (NPS) land; thus a third party locator would be required.

Pre- Charrette Comment #3:

In addition to the National Environmental Policy Act (NEPA) analysis and documentation requirements, since the project area is on federal land, some of the required permits could include:

1. NPS Special Use Permit;
2. DC Department of Consumer and Regulatory Affairs Building Permit;
3. DC Sediment Control and Stormwater Management Permits;
4. United States Department of Interior Permit for Archeological Investigations.

Pre- Charrette Comment #4:

Study mentions that NPS does not issue easements, just 10-year right of way permits. Project would need to work through these issues.

Concerns:

- There is no mention of various permits in review materials provided.

Recommendations:

- Consider the required NEPA process as the proposal is on federal land. This would require an analysis of alternatives and environmental and socioeconomic impacts of each.
- Ensure consideration of all permits:
 - Potentially required permits could be associated with NPS, DC Government, DDOT, Federal Government stakeholders.
 - Allow appropriate time for issuance of all permits.

5.13 IMPACTS TO NATIONAL MALL DURING CONSTRUCTION

Pre- Charrette Comment #1:

There would be major impacts to the National Mall during construction; including impacts to recreation, tourism and special events.

Concerns:

- Work being done to the 9th and 12th St. NW tunnels may impact transportation in the area.
- Conflicting priorities between land owners in the study area for impacts during construction.
- Various events held on the National Mall would likely be affected.

Recommendations:

- Recommend incorporation of transportation plan, lane closures, etc. for the construction period
 - Potential coordination with DDOT.
 - Would be important for coordination and garnering support from surrounding agencies.
- Recommend early engagement and close coordination with NPS and other entities. All stakeholders must have early input into the final concept of the proposed facility.

5.14 CONSTRUCTION SCHEDULE

Pre-Charrette Comment #1:

Clark's 2 level Design/Bid/Build schedule shows a 773 day duration. It also shows that site setup/grading/dewatering and entry tunnels begin 157 days before notice to proceed (NTP) and end before or right around the issuance of the NTP. A few other activities also begin before NTP. In addition, the schedule does not show the 144 days required for Clark to assemble a shoring and dewatering plan as shown on their Design/Build schedule. The plan must be prepared by Clark and thus would increase the duration of the project. However, some amount of time may be able to be deducted from the 274 days that Clark has assumed for developing bid documents & permitting prior to NTP.

Concerns:

- Current schedules are for older designs and require refinement with new concepts.

Recommendations:

- Upon selection and refinement of concept designs, recommend updating the schedule.
- Breakout design phase to detail timeframe for client review, civil/site/utilities plans, shoring and dewatering plan, footing & waterproofing plans, and mechanical, electrical, and plumbing (MEP) systems/finishes.
- Include time for obtaining required permits and locating utilities which include potential tunnels and security related ductbanks.

5.15 COST ESTIMATES

Pre-Charrette Comment #1:

Currently the Federal Triangle area stormwater system uses both a gravity storm sewer system and a combined sewer system that takes the flow to pump stations and the waste water treatment plant (WWTP). Part of this project would have to include the construction of a new stormwater collection system. The July 2011 report states that the project cost for Alternative E (storage below Mall) is \$400M. In various documents, the project is estimated to cost \$130-\$230M. Does this cost not include the new stormwater system?

Pre-Charrette Comment #2:

Overall cost estimates provided are not equal in various reviewed documents.

Responses from Charrette:

During the charrette, Project Architect Moore stated that the Coalition expects that, any costs associated with stormwater sewer upgrades north of the project area, be funded by other stakeholders. The Coalition also acknowledged that concept designs and costs would require further refinement.

Concerns:

- The current concept does not factor sewer upgrades which seem to be of high importance to the overall function of the project. These costs may greatly impact the overall costs of the project.
- Without refined costs, there is no way of accurately quantifying the project's cost effectiveness.

Recommendations:

- Per charrette discussions, concept designs and costs would need to be refined.
- Develop a breakdown of project costs that is all-inclusive, even if part of the project is to be paid for by the government or a separate entity. This would clearly delineate the cost effectiveness of the

project. Other items that could cause costs to increase may include discharge line runs, street and sidewalk replacements, and treatment facility costs for detained stormwater.

5.16 ADDITIONAL CONSIDERATIONS

Pre- Charrette Comment #1:

While the proposed concept has merit and extensive valuable work has been done to date, there could be additional concepts for improving flood risk and parking issues which could be further explored and conceptually developed. This may or may not lead to an improved concept, or it may provide a contingency concept should the current concept hit a future impasse. Processes that are advantageous generally in these regards are alternatives evaluation and risk-based decision making. There may also be areas of the current concept that can be refined technically through additional considerations.

Concerns:

- Interior flooding may not be alleviated to the extent envisioned by the proposed project without major renovations to existing infrastructure to include existing systems upsizing, existing buildings upgrading (watertightness), and extensive grading.
- The contribution of groundwater levels to prior flooding is also unclear from the documentation reviewed and it is unknown if it could still pose some concerns with the proposed project.

Recommendations:

- Better determine what flood volume is expected to be able to be transported to the reservoir given the above limiting factors. Consider whether meaningful benefits may be obtained at a better benefit/cost ratio by downsizing the current reservoir size proposed, to a size that agrees with what existing infrastructure can transport with minor rather than major improvements. This may potentially allow the remaining flood volume to be handled with an overall less costly approach. Consider whether there would be groundwater-related concerns even with project construction.
- Consider whether interior flooding could be alleviated sooner than later and more cost effectively if the proposed reservoir project did not attempt to incorporate parking functionality, and vice versa. For example, there could be some cost increase for adjacent subsurface structures serving two different purposes, but complexities (e.g. security-related, life safety, operational challenges) which are currently not all identified nor detailed at this level of the concept, could ultimately make the current proposal much more costly than another concept. The current concept considers life-safety related concerns and has proposed conceptual strategies to minimize risk; continued work along these lines is valuable.
- For designing flood risk management, USACE as stated above incorporates risk-based analysis and decision-making, meaning more rigorous probabilistic versus more limited deterministic approach, and focuses on benefit versus costs in terms of economics and life safety. This approach could be advantageous for helping further optimize what the ideal size for the reservoir would be. If future study changes what is currently viewed as the ideal storage reservoir size, a different concept may be required.
- Consider whether there could be any desire for a multi-purpose barrier around the National Mall to serve as a security feature for events and as a very infrequent stormwater detention basin. Consider if there are any recreational areas within close enough proximity to the flooding that some stormwater could be routed via gravity flow and temporarily stored there, or if there is the potential for creating engineered urban areas which infrequently serve as detention basins. For example in Rotterdam (and elsewhere) there are water plazas utilized to reduce pressure on storm systems in a controlled manner; when not infrequently under a few feet of water, such plazas can

be public recreational areas or other purpose. There may be other means of reducing inflow to the current problematic system to some extent, which could allow a smaller reservoir to be required in conjunction with the parking facility and thus reduce costs.

- Clearly demonstrate why this synergistic solution is in the best interest of the stakeholders versus other identified solutions. This may include life cycle analyses and developing financing strategies for the cost of construction, operation, and maintenance. This should be developed within a written report that provides more clarity and details of total project costs and the level of flood risk management that is being provided.
- Documentation of the benefits that would be achieved through the construction and implementation of this project as compared to the costs would be helpful supporting information. Describe physical damages that the design flood event would cause to the area of impact without the project, and if those damages include more than the contents at or below the flood level. Often materials that require climate control can be damaged if the systems that support them go down.

Pre- Charrette Comment #2:

All electrical/mechanical components below flood storage elevation would have to be flood proofed, or thoroughly dried/re-greased after each event.

Concerns:

- If electrical/mechanical systems in flooding level are not designed adequately for submergence, maintenance and repair costs and facility closure times may be much larger than estimated.

Recommendations:

- Recommend minimizing any electrical/mechanical systems placed in the flooding level. Place all electrical no lower than the ceiling of the flood level, except that required to power submersible pumps. Use immersion connections for all electrical exposed to the flooding level.

6.0 CONCLUSION

The purpose of this effort was for USACE to provide a technical review of the multi-functional parking garage and underground storage concept, known as the National Mall Underground (the “Underground”). The intent of the Underground is to reduce interior flooding risk that currently threatens the Federal Triangle area while providing improved access to the National Mall through increased parking capacity. USACE reviewed existing documentation prepared by both the public and private sectors, as listed in Section 4 and summarized in Appendix A, to evaluate the technical aspects of this flood risk reduction alternative and coordinated closely with the Coalition to clarify early questions and concerns related to the concept plans.

As a result of this technical review, the Coalition is being provided a set of concerns and recommendations that may be used to further develop their concept designs. The USACE technical review team was comprised of experts in the Civil, Structural, Hydrology, Electrical/Mechanical, Geotechnical, Planning, and Construction disciplines, and concerns and recommendations were organized into overarching topics.

The Underground offers an innovative, multi-purpose potential alternative for stormwater retention and flood risk management on Constitution Avenue and in the Federal Triangle area. Concurrently, it could

address the documented need for tour bus parking⁶, as well as provide a tourism visitor center, geothermal energy, and irrigation for the National Mall turf grass and gardens. Additionally, revenue potential from parking fees and water credits may offer self-financing opportunities that attracts a public-private partnership. However, further study is needed, particularly on the conceptual systems related to phased floodwater intake and evacuation of buses to minimize risk to life safety during a flash flood. Due to the conceptual nature of the overall proposal, feasibility for the Underground was not determined under this current effort. Potential technical feasibility may be evaluated in the future based on key technical review considerations described in Table 1.

Table 1: Key Technical Review Considerations for Determining Potential Feasibility

Key Technical Review Consideration	Concerns to be Addressed in Future Stages of Development
Can the Underground reduce risk of flooding on Constitution Avenue and in the Federal Triangle area?	Flood risk from a storm of the intensity that flooded the Federal Triangle area in 2006 could be reduced significantly during a flood event by implementation of the Underground. However, further study is needed of the proposed phased floodwater intake system, where water is drawn into compartmentalized parking areas to allow for proper evacuation of vehicles, to demonstrate its capacity to receive and remove floodwater from the study area in a timely manner. This is of particular concern during a flash flood event, when limited warning time may impact the operations of the facility.
Can the Underground be operated and evacuated efficiently to minimize life safety risk during a flash flood event?	The primary concern is effective and timely evacuation of any and all persons from the floodable areas of the Underground, that is, the lower bus level. Further study is needed to evaluate various alternatives for the safe evacuation of the Underground, including the Coalition’s proposed automated bus parking system. Forecasting technology and warning time is limited for flash flood events and this may impact decision making triggers for operations of the facility. There are concerns with evacuating a large number of buses out of a confined lower level in a timely manner, and potential backups in the exit ramp of the proposed facility. A detailed operations plan, to include lower level compartment filling and bus evacuation timing, should be developed to identify decision making triggers for the utilization of the facility for flood storage.
Does the structure have enough capacity to store floodwaters for the 200-year flood?	The 2011 Study identified a required 24 million gallons of surface water flood storage for the 200-year storm. The latest concept allows for 30 million gallons of storage according to the Coalition. Further detailed modeling/design may be required.

⁶ Need for tour bus parking was identified in the following reports: National Mall and Memorial Parks Tour Bus Study (NPS, 2015), A Review of Access and Circulation on the National Mall in Washington, D.C. (GMU, 2008), District of Columbia Motorcoach Action Plan (DoT, 2011), and Regional Bus Staging, Layover, and Parking Location Study (MWCOG, 2015)

Key Technical Review Consideration	Concerns to be Addressed in Future Stages of Development
Can water be conveyed into and out of the facility?	More information is required to analyze the stormwater system upgrades and determine pumping requirements. The project should ensure reliability and redundancy of the pumping system.
Can rainwater / groundwater harvesting cisterns be used for managing floodwaters?	There may be a limited ability to manage flood storage in the cisterns. Further analysis is required to determine whether storage could become available quickly enough to accommodate a subsequent flood. There is concern over water quality within the cistern and if toxic water can be treated for reuse.
Are the soil and groundwater conditions suitable for building an underground parking garage in the study area?	Limited soil and groundwater data was provided. A site explorations program is required to determine groundwater and soil conditions.
What is the structural feasibility of constructing an underground storage garage?	All structural loads would have to be designed per governing codes. It is anticipated that the deeper the structure extends, the more difficult the construction would become and more costly to both construct and maintain.
Are there any underground utilities/facilities that could be adversely impacted by the proposed Underground?	There are potential conflicts with the Underground early stage concept layout and surrounding current and future underground facilities and/or utilities. Further investigation of infrastructure and coordination with surrounding entities should be conducted.

Key recommendations from the USACE technical review should be considered in future phases of design. A summary of some of the key recommendations, which are further detailed throughout the report, include:

1. Perform an operational risk analysis to ensure life safety and define trigger points for beginning evacuation of people and vehicles from the structure before and during an event. Due to limited technology, forecasting of severe rain events would continue to be a challenge for the operation of this facility. Separating flood storage and parking area should be considered.
2. Identify any existing and/or proposed underground facilities or utilities in the project area.
3. Further develop a detailed evacuation plan for bus removal during a future flood event.
4. Perform additional analysis to determine the required modifications to the existing stormwater system to allow conveyance of floodwaters into the proposed underground storage system.
5. Evaluate pumping requirements for stormwater and groundwater. Determine pumping station locations of project site.
6. Further refine concept for controlled filling of stormwater into the structure.
7. Further refine concept for emptying structure between storm events, including the usage of rain water/groundwater harvesting cisterns for flood storage.
8. Conduct a study of the reliability of electric power supply during extreme rainfall events.
9. Perform site exploration, including borings and continuous sampling/testing along the alignment to identify heterogeneities that could impact or need special consideration during design and construction. Determine groundwater elevations to support future design work.

10. Determine the requirement for treating the discharged water to better understand the required design and costs associated with the concept.
11. Further refine cost estimates in order to perform detailed economic analysis.
12. Continue to coordinate with stakeholders to determine needs and concerns throughout future iterations of the concept design.

USACE did not review or consider other alternatives to the stormwater flooding problem during this technical review. USACE recommends that further development of the Underground, and of any flood risk management project in the Washington, D.C. area, be a part of a collaborative, interagency process for a comprehensive and resilient solution, as there are many land owners and stakeholders required for implementation of any solution.

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APPENDIX A:
LIST OF REVIEWED MATERIALS

USACE DOCUMENT GAP ANALYSIS				
YEAR	STATUS	DOCUMENT	COMPANY	RECEIVED BY USACE?
CONFORMANCE WITH EXECUTIVE ORDERS AND FEDERAL LAWS				
2014	Complete	Compilation of Underground features as complying with Executive Orders and Laws regarding resiliency, sustainability, flood and drought mitigation, congestion and pollution, etc.	Various Documents	Yes
COST BENEFIT ANALYSIS				
2014	Completed	Cost-benefit analysis evaluating earlier design, <i>before the addition of automated parking and geothermal components.</i>	Partners for Economic Solutions	Yes
2015	Pending	Revision of cost-benefit analysis (see above)	Partners for Economic Solutions	No
2015	Complete	Cost-benefits of resiliency aspects of the Underground	Dewberry	Yes
DESIGN CONSTRUCTION COSTS AND TIMELINES				
2014	Complete	Design-bid-build-estimates. Donated services estimating 2-story and 3-story versions of the project. <i>Before addition of automated parking and the geothermal component</i>	Clark Construction	Yes
2016	Pending	Design-bid-build estimates		No
FLOODING REPORTS				
2007	Complete	Study for flood proofing only GSA buildings in the Federal Triangle area	GSA	Yes

2011	Complete	Federal Triangle Stormwater Drainage report. This report proposes constructing a stormwater reservoir under the Mall, but the report was put on the shelf as no agency/entity had jurisdiction of funding to build. This report is the basis for the multi-use parking garage/floodwater reservoir.	DC and NCPC (plus 14 federal and DC agencies)	Yes
GEOHERMAL				
2015	Complete	Proof of Concept Analysis, Proposed Geothermal Wellfield, Nation Mall	Wiley/Wilson	Yes
NATIONAL MALL UNDERGROUND PLANS & DRAWINGS				
2011-2012	Complete	Engineering studies of best Mall location and potential design of a car parking facility	Dewberry	Yes
2011-ongoing	Ongoing	Arthur Moore continues to revise design to accommodate multiple features including stormwater reservoir, irrigation cisterns, visitor's center, and geothermal.	Arthur Moore	Yes
2016	Complete	Revised illustrations of Underground and Automated Garage feature.	Arthur Moore	Yes
PARKING DEMAND				
2014	Complete	Traffic Demand Study	Gorove Slade	Yes
PARKING REVENUE				
2013	Complete	Donated services. Estimating revenue from car and bus parking.	Colonial Parking	Yes
2016	Pending	Update of parking revenue setting higher fees for bus parking (higher than \$60)		No

TOUR AND COMMUTER BUS ACCESS AND PARKING				
2008	Complete	Access and Circulation study (transportation graduate students study)	George Mason University	Yes
2011	Complete	Motorcoach Action Plan	DC DOT	Yes
2013-2014	Complete	Multi-part analysis of tour bus operations and parking (done for National Parks Service)	George Mason University	Yes
2015	Complete	Report on need for tour bus parking	George Mason University	Yes
2015	Complete	Study for the tour bus problem	MWCoG	Yes
2016	Pending	Traffic Study Coordinated with DC OP	Gorove Slade	Yes
WATER RESOURCE BUDGET				
2014	Complete	Water Budget Technical Report (working with DDOEE) of stormwater and other credits from harvesting rainwater from Mall area includes Smithsonian museum roofs	Dewberry	Yes
GEO TECHNICAL				
2013	Complete	National Mall Turf Grass Restoration	NPS	Yes
OTHER REPORTS				
2017	Draft	South Mall Campus EIS	Stantec	Yes

APPENDIX B:
CHARGE QUESTIONS AND REVIEW PRIORITIES

The questions below were formulated to help guide the technical review process for the various discipline experts.

Primary Goal Question:

Is this project technically feasible to meet the project goal of flood risk reduction?

H&H (Hydrologists):

Questions: Is there enough capacity for storage (~24 Million Gallons) to reduce flood risk in the project area.

- What are the major concerns and risks?
- What other information is needed?
- What would be the key recommended steps (analysis) moving forward?

Ancillary Questions:

- Can the study area receive water from existing infrastructure/groundwater (DC Water)?
- Rainwater and groundwater harvesting?
 - Considering risk of evacuating vehicles
 - Life-safety concerns

Geotechnical:

Questions: Are the soil and groundwater conditions suitable for building an underground parking garage in the study area?

- What are the major concerns?
- What other information is needed?
- What would be the key recommended steps (analysis) moving forward?

Ancillary Questions:

- Would the site conditions support a slurry wall/retaining wall?

Electrical/Mechanical:

Questions: What pumping requirements would there be based on volume of storage?

- What are the major concerns?
- Where could water be pumped to?
- Is the study area suitable for a pump station?
- What other information is needed?
- What would be the key recommended steps (analysis) moving forward?

Ancillary Questions:

- Is there pumping required to transport floodwaters from north of the study area using existing infrastructure?

Construction:

Questions: What is the feasibility of constructing the project in the study area?

- What are the major concerns?
- What other information is needed?
- What would be the key recommended steps (analysis) moving forward?

Ancillary Questions:

- What are some of the added costs to constructing in DC?
- What are the added costs of federal construction vs private construction?
- How do you coordinate with the various property owners (District and federal agencies)?

Civil/Structural:

Questions: What is the feasibility of constructing an underground storage garage in the study area?

- What are the major concerns?
- What other information is needed?
- What would be the key recommended steps (analysis) moving forward?

Ancillary Questions:

- Are there concerns with vehicles exiting the facility in a timely manner?

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APPENDIX C:
INITIAL COMMENTS PRIOR TO CHARRETTE

INITIAL COMMENTS PRIOR TO CHARRETTE

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Table 1: EXPECTING RAIN

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Geotech.	<p>Could interior flooding be alleviated sooner than later and more cost effectively if the proposed reservoir did not attempt to incorporate parking functionality, and vice versa? For example, there could be some cost increase for adjacent subsurface structures serving two different purposes, but complexities (e.g. security-related, life safety, operational challenges) which are currently not all identified nor detailed at this level of the concept, could ultimately make the current proposal much more costly than reflected in current estimates. Have separate facilities (or other concepts) been fairly well considered and costed?</p>
Civil	<p>Key Recommendation - One of the biggest concerns with this concept is the ability to execute during an event while evacuating all vehicles from the flooded levels of the structure. In order to closely analyze this concern, it is recommended that an operational risks assessment be conducted on the proposed concept. All time lines, procedures, and personnel required for operation could be analyzed in depth and run through <i>Monte Carlo simulations</i>. Report would include: defining trigger points when operations need to begin; defining minimum and maximum time elements for each operational step; worst case scenarios (middle of the night on a holiday weekend or perhaps street traffic jams backing up the ability for vehicles to leave out exit ramps); defining required work crews to operate the system; etc...</p>
Civil	<p>Major Concern - Time to react from trigger point and how the trigger point is monitored would be key within the operational risks analysis. Execution of operations would have very limited time since the watershed is very small.</p> <p><i>Question for the ATR team – What are our recommendations on how to define a trigger point to begin execution of operation plan?</i></p> <p><i>a. Is this based on a gage (or floats) within the storm drain or street intake structures? – Way too late to allow time for execution.</i></p> <p><i>b. Is it based on a combination of precipitation and intensity amounts? – Again, information coming in may be too late for timely execution.</i></p> <p><i>c. Is it based on future forecast or events on radar heading into the region? - Weather forecast have a lot more uncertainty and generally are not used for FRM operation decisions.</i></p>

Civil	<p>Major Concern - Risks and liability to owners of vehicles and contents that park within the flood zone of the underground structure needs to be clear cut. It is assumed that flooding the system would begin when an operational trigger point is reached whether or not vehicles remain within the flood zone of the structure. There are thousands of scenarios where the owners of vehicles may not get the message in time to move their vehicles ahead of the structure being filled with stormwater.</p> <p><i>Possible solutions might be tied to limiting parking access to flood levels of structure. This could include ensuring flood levels are cleared of all vehicles every night – structure can only be occupied from xx time am to xx time pm or limit parking time to just to 2 to 4 hours per vehicle. If weather forecast calls for x amount of rain in the next 24 hours – the flood levels of structure do not open for vehicles on those days.</i></p>
Civil	<p>There would be events through the years that hit the action trigger point requiring evacuation of vehicles but ultimately the event does not end up large enough to require the underground structure to be filled with any stormwater. These trigger events, which cause evacuations yet no filling of the structure, must not sway future operation actions to execute at the set trigger point.</p>
H&H	<p>What are the major concerns and risks? Developing a plan to evacuate the parking areas to allow for flood storage would be a challenge. The type of storm that this facility is designed for is a <i>flash flood</i>. The only "warning" available would be forecast based. Meaning, the NWS would predict a heavy rainfall and it may or may not occur, and when exactly high flows in the underground facility would be expected would be nearly impossible to predict. There would be a significant risk that vehicles would get trapped in the facility, or, on the other end of the spectrum, the facility be evacuated when it wouldn't be needed.</p>
H&H	<p>The evacuation plan should have triggers for various conditions to prevent drowning or death/injury from a chaotic evacuation situation, these should be conservative/simple given the uncertainty of human behavior.</p>
H&H	<p>During flash flooding events that are characteristic of summer thunderstorms, the provided information has not demonstrated that it is reasonable to assume that the vehicles would be evacuated. The cost and environmental impacts of flooded vehicles should therefore be included in consideration of this option.</p>
Planning	<p>Concerned with buses parking on a level that would be flooded during a high flood event. When and who determines when buses can and cannot park there? There is limited flood warning time for this type of interior flooding. It would be a major life safety issue to have buses and bus drivers in an area that can be submerged. Would it be closed to buses if heavy rain is predicted? If significant rain starts during the day and it must close, how are bus drivers notified?</p>
Planning	<p>How much time would it take the buses to evacuate if heavy rain starts during the day? Concerned with bus drivers being trapped in the garage.</p>
Planning	<p>Where would the buses park on days that the facility is closed if they had planned to park there?</p>
Planning	<p>How good is the traffic flow out of the garage if it needs to be evacuated quickly?</p>

Table 2: HEAVY RAIN

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
H&H	<p>What are the major concerns and risks? None of the documentation provided addresses how the stormwater would get to the underground facility. In both flood studies (2011 FEDERAL TRIANGLE STORMWATER DRAINAGE STUDY; 2007 GSA_DC_Flood_Study_Draft_01232007) it is noted that significant improvements to the existing stormwater infrastructure is needed. The primary cause of the 2006 flooding was that there was too much rain and the size/condition of the existing stormwater pipe network could not handle the runoff. Thus, the pipes get full, water backs up out of inlets/manholes, and water ponds on the roads. If improvements to the stormwater system (pumps to the underground facility or pipe enlargements) do not occur with this project, flooding would continue, because the pipes are not big enough to handle the flow. The underground facility could be designed to handle a 200-year volume of water, but if the pipes are not designed to convey a 200-year flow to that facility, it does not make a difference. To get water to the underground facility and eliminate overland flooding, significant, costly improvements would be needed and are not accounted for in any design/cost/benefit-cost document provided in this document. For example, a pipe currently sized at 12" may need to be enlarged to 36" to accommodate, and it is possible that large tunnels would be required. Not only would mainline pipes need enlarged, but secondary lines as well. The GSA study states that stormwater improvements/pump station could be \$5M-\$10M. The 2011 Federal Triangle Study does not give costs. But the stormwater system improvements needed to get the water to this underground facility would be very costly (which could change economic analyses) and would disturb traffic in the entire National Mall area for years.</p>
H&H	<p>What other information is needed and what would be the key recommended steps (analysis) moving forward? An analysis of the stormwater system improvements that would be required to get the water to the underground facility is required. A 1D/2D stormwater model would be required to determine the pipe sizes and/or pump capacity needed to get the water to their underground facility. Once this information is determined, a cost associated with these required improvements can be determined and added to the economic analysis.</p>
H&H	<p>28.5-million gallons is approx. 88-acre-feet; which relates to approx. 0.3-inches of runoff for a 5.8-square-mile drainage area. This is a small fraction of the rainfall of even a 6-hour/200-year storm. Although the reviewer appreciates the complexity of the urban drainage system and how a large majority of that contributing area is otherwise managed by the existing infrastructure, a total water budget should be developed to simply understand the water stored in buildings, other underground infrastructure, surface, and conveyed through the existing combined system.</p>
H&H	<p>The description of the hydrologic model (Greenly and Hansen, 2011) used to develop the frequency design storms illustrates that it is a very complex system, with many parameters and boundaries. The model is really only calibrated to a single event (2006). In addition, it is described that the drainage area itself is a calibration parameter (e.g. 40-percent). Based on this information, I would characterize the confidence in the hydrologic model as low and should be supplemented in order to develop a required storage requirement.</p>

<p style="text-align: center;">H&H</p>	<p>A longer duration than 6-hours should be evaluated for a storage solution. Any duration where the existing facilities capacity is exceeded would contribute to the elimination of the underground storage capacity.</p>
<p style="text-align: center;">H&H</p>	<p>Based on the reviewed documentation, it is unclear if there is a potential for the required flow/volume of water to minimize flooding from a 200-year event storm event. Based on limited understanding of the overall system and topography, it is likely possible; but with the available information, I cannot provide an opinion on feasibility.</p>
<p style="text-align: center;">Geotech.</p>	<p>Prior interior flooding may not be alleviated to the extent envisioned by the proposed project without major renovations to existing infrastructure to include existing systems upsizing, existing buildings upgrading (watertightness), and extensive grading. What is the flood volume that is expected to be able to be actually transported to the reservoir given the above limiting factors? Could meaningful benefits be obtained at a better benefit/cost ratio by downsizing the current reservoir size proposed, to a size that agrees with what existing infrastructure can transport? Can remaining flood volume be handled with another overall less costly approach?</p>

Table 3: WATER IS COMING

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Structural	Should research groundwater elevations during flood events. If groundwater levels are high during flooding, and are slow to recede, the structure would have to be designed for these hydraulic loads, or not dewatered until they have receded.
Civil	Filling of stormwater into the underground structure would need to be controlled, either by means of gates or a pump system to prevent premature flooding of the structure before all vehicles are evacuated and to prevent overfilling of the structure if the top underground level is to remain dry.
Civil	System components should take into account redundancy and have backup plans if primary flood risk management components fail or break.
Elect/Mech.	Realizing design is conceptual, but no space is set aside for pump station, controls, or electrical equipment on any of the levels in the sketches supplied.
Elect/Mech.	An evaluation of the reliability of electric power would need to be performed and possibly backup power supplied for pumping and other emergency loads included.

Table 4: TAKING WATER OUT

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Elect/Mech.	Where could water be pumped to? Most direct route seems to be to the tidal basin. Probably would need redundant backflow prevention, e.g. flap valve and slide gate that closes in an emergency, on the discharge pipe.
Elect/Mech.	Is the study area suitable for a pump station? I see no technical reasons why a pump station could not be a part of the facility. What makes this unusual, is that it would be a pump station with a ponding area that is normally occupied and would require evacuation prior to being able to utilize the storage.
Structural	Gravity drainage for this structure would likely not be permissible due to its depth. Pumps, likely mounted near surface elevation, would be required to remove normal and flood event rain water from the structure. Measures would have to be made to minimize any exhaust and noise created.
Structural	Large amounts of silt (leaves, trash) cleanup would be required after floodwater storage event. All electrical/mechanical below flood storage elevation would have to be flood proofed, or thoroughly dried/re-greased.
Civil	Due to depth of structure, emptying of stored stormwater would likely require the use of a pumping system . The ability to handle accumulation of sediment deposits and scum should be anticipated after each event . Pavement markings, signs, etc... would need to be scoured clean. Cleaning and proper ventilation of all submerged surfaces to prevent mold and mildew from forming would be necessary.
H&H	Rainwater and groundwater harvesting? This would be technically feasible and a benefit to this project. However, the water would need to be harvested immediately after the storm to not reduce the effectiveness of the facility to store floodwaters . If two large storms were to happen back to back, and the water were to not be released from the first storm, the capacity of the underground facility would be reduced for the second storm. This issue is not addressed in any of the documentation.
H&H	Based on the reviewed information, it is believed that rainwater harvesting would be limited to smaller events . The major events are a challenge for two reasons: 1. The water would need to be immediately pumped to be available for additional periods of intense rainfall within that event and future events, and 2. The major events would likely flood numerous vehicles and would therefore contaminate the area with volatile organic compounds.
Planning	Would there be health issues in the flood/parking level following a flood event ? Mold, bacteria concerns? How would this be handled?

Table 5: CONSTRUCTABILITY

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Construction	Clark's 2 level Design/Bid/Build schedule shows a 773 day duration. It also shows that site setup/grading/dewatering and entry tunnels begin 157 days before notice to proceed (NTP) and end before or right around the issuance of the NTP. A few other activities also begin before NTP. In addition, the schedule does not show the 144 days required for Clark to assemble a shoring and dewatering plan as shown on their Design/Build schedule. The plan must be prepared by Clark and thus would increase the duration of the project. However, some amount of time may be able to be deducted from the 274 days that Clark has assumed for developing bid documents & permitting prior to NTP.
Construction	Some of the required permits are: 1. NPS Special Use Permit; 2. DC Department of Consumer and Regulatory Affairs Building Permit; 3. DC Sediment Control and Stormwater Management Permits; 4. United States Department of Interior Permit for Archeological Investigations
Geotech.	Additional review of existing data and reports concerning regional and local hydrogeology could be advantageous with regards to project design, cost estimation, and construction. For example, the USGS has some existing reports concerning groundwater of the area, and these reports contain many references which also appear to concern groundwater information that should be generally helpful. Also, research and obtainment of any existing data concerning groundwater-related design and possible difficulties during construction of nearby structures should be possible and advantageous. For example slurry walls have been used on the WW2 memorial and some museums surrounding the mall, as indicated at this link: http://scholarsmine.mst.edu/cgi/viewcontent.cgi?article=2908&context=icchge.
Geotech.	While some subsurface data exist, an exploration program for the proposed construction area is intended to be conducted - per the cost estimate provided. The estimated amount may be too low considering what information is ideally needed. Furthermore, soil sequences resulting from the fluctuation of sea level and glacial meltwater inflow are often highly variable requiring frequent data to characterize. More borings and continuous sampling/testing should be performed along the alignment to identify heterogeneities that could impact or need special consideration during design and construction. For example, the Schnabel 2011 work occasionally encountered Weight of Hammer (WOH) material in alluvial strata beneath fill, and perched water zones; the anticipated inflow for a deep excavation may be difficult to reliably estimate at this time without more data. At the reference link above and in other references it is discussed that many of the monuments have encountered poor soil conditions and therefore deep foundations were required. The reflecting pool for example involved composite piles driven to rock and several structures with shallow systems have experienced problematic settlement. The exploration/testing program should further define groundwater in terms of perched and year-round static water level variations, and pump-testing utilizing new monitoring wells could provide important bulk permeability information relevant to construction dewatering needs estimation. As well, this data would help the design of drainage and waterproofing needs for the proposed structure. These data and perhaps preparation of a Geotechnical Baseline Report would serve to reduce uncertainty and could ultimately be a good return on investment by leading to lower cost proposals by bidders.

Structural	If constructed, the entire structure should be supported, or fit over the footprint of the lowest level. When the lower levels are filled with stormwater, it would be desirable for the entire structure to settle uniformly. The other option is to found the structure directly on rock.
Civil	All equipment and features within the flooding levels of the structure would need to be designed for submergence. This may include lights, motors, elevators, electrical lines, mechanical equipment, etc...
Civil	Inspection, operational testing, and personnel training on flood risk management components should be required at least once every year at a minimum. (Definitely required if system is entered into and approved for the PL84-99 program.)
Civil	Conflicts with 2017 Smithsonian Institution, South Mall Campus Master Plan for the alternatives that call for underground expansion. Specifically the vicinity where the proposed parking structure access ramp connects in-between the underground structure and daylighting out towards Independence Avenue.
Planning	There would be major impacts to the National Mall during construction; including impacts to recreation, tourism and special events.
Planning	Study mentions that NPS does not issue easements, just 10-year right of way permits. Project would need to work through this issue.

Table 6: COSTS

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Planning	How fast can the flooded level be pumped out and what type of cleaning must be done before the buses can park in the facility ? May lose days of revenue after a flood.
Planning	Currently, the Federal Triangle area stormwater system uses both a gravity storm sewer system and a combined sewer system that takes the flow to pump stations and the WWTP. Part of this project would have to include the construction of a new stormwater collection system. The July 2011 report states that the project cost for Alternative E (storage below Mall) is \$400M. In the various documents, the project is estimated to cost \$130-\$230M. Does this cost not include the new stormwater system?

Table 7: GEOTECH

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
<p>General</p>	<p>Presumably some site-specific data exist and engineering evaluations have previously been performed which this review is not aware of given its scope and materials provided. For example, the 2011 Feasibility Study by Dewberry stated conceptual plans for possible underground garages were based on " cursory engineering evaluations related to site, structural, and geotechnical considerations..." Moving forward, more specific suggestions could perhaps be offered should more data become available and as future studies/designs proceed.</p>
<p>General</p>	<p>Additional review of existing data and reports concerning regional and local hydrogeology could be advantageous with regards to project design and cost estimation and construction. For example, the USGS has some existing reports concerning groundwater of the area, and these reports contain many references which also appear to include groundwater information that should be generally helpful. Also, research and obtainment of any existing data concerning groundwater-related design and possible difficulties during construction of nearby structures should be possible and advantageous. For example slurry walls have been used on the WW2 memorial and some museums surrounding the mall, as indicated at this link: http://scholarsmine.mst.edu/cgi/viewcontent.cgi?article=2908&context=icchge.</p>
<p>General</p>	<p>While some subsurface data exist, an exploration program for the proposed construction area is intended to be conducted - per the cost estimate provided. The estimated amount maybe too low considering what information is ideally needed. Furthermore, soil sequences resulting from the fluctuation of sea level and glacial meltwater inflow are often highly variable requiring frequent data to characterize. More borings and continuous sampling/testing should be performed along the alignment to identify heterogeneities that could impact or need special consideration during design and construction. For example, the Schnabel 2011 work occasionally encountered Weight of Hammer (WOH) material in alluvial strata beneath fill, and perched water zones; the anticipated inflow for a deep excavation may be difficult to reliably estimate at this time without more data. At the reference link above and in other references it is discussed that many of the monuments have encountered poor soil conditions and therefore deep foundations were required. The reflecting pool for example involved composite piles driven to rock and several structures with shallow systems have experienced problematic settlement. The exploration/testing program should further define groundwater in terms of perched and year-round static water level variations, and pump-testing utilizing new monitoring wells could provide important bulk permeability information relevant to construction dewatering needs estimation. As well, this data would help the design of drainage and waterproofing needs for the proposed structure. These data and perhaps preparation of a Geotechnical Baseline Report would serve to reduce uncertainty and could ultimately be a good return on investment by leading to lower cost proposals by bidders.</p>
<p>General</p>	<p>Prior interior flooding may not be alleviated to the extent envisioned by the proposed project without major renovations to existing infrastructure to include existing systems upsizing, existing buildings upgrading (watertightness), and extensive grading. What is the flood volume that is expected to be able to be actually transported to the reservoir given the above limiting factors? Could meaningful benefits be obtained at a better benefit/cost ratio by downsizing the current reservoir size proposed, to a size that agrees with what existing infrastructure can transport? Can remaining flood volume be handled with another overall less costly approach?</p>

<p style="text-align: center;">General</p>	<p>Could interior flooding be alleviated more effectively by constructing a drainage channel or conduit system directed to a ponding area and pump station near the river? There is a fair amount of undeveloped land between the problem flood area, the National Mall, and the river. This is a general approach towards interior flooding that is utilized regularly across the nation with levee/floodwall systems. This approach, if feasible, could reduce many complexities associated with construction beneath the Mall. This concept also may be more easily upsized to handle larger floods than the current project proposal if that is desirable and deemed cost effective. Available undeveloped ground in these areas may also allow the construction of a less costly surface parking facility than that currently proposed.</p>
<p style="text-align: center;">General</p>	<p>Could interior flooding be alleviated sooner than later and more cost effectively if the proposed reservoir did not attempt to incorporate parking functionality, and vice versa? For example, there could be some cost increase for adjacent subsurface structures serving two different purposes, but complexities (e.g. security-related, life safety, operational challenges) which are currently not all identified nor detailed at this level of the concept, could ultimately make the current proposal much more costly than reflected in current estimates. Have separate facilities (or other concepts) been fairly well considered and costed?</p>

Table 8: STRUCTURAL

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
General	Must have controlled flow of stormwater into the parking area. Would have to have an evacuation procedure and method to prevent human or unauthorized entry during stormwater retention. There are potential life safety concerns if reliable evacuation and preventative re-entry processes cannot be established.
General	Gravity drainage for this structure would likely not be permissible due to its depth. Pumps, likely mounted near surface elevation, would be required to remove normal and flood event rain water from the structure. Measures would have to be made to minimize any exhaust and noise created.
General	Large amounts of silt (leaves, trash) cleanup would be required after the floodwater storage event. All electrical/mechanical below flood storage elevation would have to be flood proofed, or thoroughly dried/re-greased.
General (GSA 2007)	Flood proofing of buildings in Federal Triangle may be more cost effective.
General	This may be a terrorist target. Security would likely have to be high.
General (2011 Flood Study)	Agree with 2011 Federal Triangle Stormwater Drainage Study, which appears that Alternative G1, Tunnel from O St. to Fed Triangle – Stop at Fed Triangle, or Alternative F, Pumping Station Serving National Mall, may be the most cost effective.
General	If constructed, the entire structure should be supported, or fit over the footprint of the lowest level. When the lower levels are filled with stormwater, it would be desirable for the entire structure to settle uniformly. The other option is to found the structure directly on rock.
General	Should research ground water elevations during flood events. If groundwater levels are high during flooding, and are slow to recede, the structure would have to be designed for these hydraulic loads, or not dewatered until they have receded.

Table 9: CIVIL

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
General	Key Recommendation - One of the biggest concerns with this concept is the ability to execute during an event while evacuating all vehicles from the flooded levels of the structure. In order to closely analyze this concern, it is recommended that an operational risks assessment be conducted on the proposed concept . All time lines, procedures, and personnel required for operation could be analyzed in depth and run through <i>Monte Carlo simulations</i> . Report would include: defining trigger points when operations need to begin; defining minimum and maximum time elements for each operational step; worst case scenarios (middle of the night on a holiday weekend or perhaps street traffic jams backing up the ability for vehicles to leave out exit ramps); defining required work crews to operate the system; etc...
General	Major Concern - Time to react from trigger point and how the trigger point is monitored would be key within the operational risks analysis. Execution of operations would have very limited time since the watershed is very small. <i>Question for the ATR team – What are our recommendations on how to define a trigger point to begin execution of operation plan?</i> <i>a. Is this based on a gage (or floats) within the storm drain or street intake structures? – Way too late to allow time for execution.</i> <i>b. Is it based on a combination of precipitation and intensity amounts? – Again, information coming in may be too late for timely execution.</i> <i>c. Is it based on future forecast or events on radar heading into the region? - Weather forecast have a lot more uncertainty and generally are not used for FRM operation decisions.</i>
General	Major Concern - Risks and liability to owners of vehicles and contents that park within the flood zone of the underground structure needs to be clear cut . It is assumed flooding the system would begin when an operational trigger point is reached whether or not vehicles remain within the flood zone of the structure. There are thousands of scenarios where the owners of vehicles may not get the message in time to move their vehicles ahead of the structure being filled with stormwater. <i>Possible solutions might be tied to limiting parking access to flood levels of structure. This could include ensuring flood levels are cleared of all vehicles every night – structure can only be occupied from xx time am to xx time pm or limit parking time to just to 2 to 4 hours per vehicle. If weather forecast calls for x amount of rain in the next 24 hours – the flood levels of structure do not open for vehicles on those days.</i>
General	Filling of stormwater into the underground structure would need to be controlled, either by means of gates or a pump system to prevent premature flooding of the structure before all vehicles are evacuated and to prevent overfilling the structure if the top underground level is to remain dry.
General	All equipment and features within the flooding levels of the structure would need to be designed for submergence . This may include lights, motors, elevators, electrical lines, mechanical equipment, etc...

<p style="text-align: center;">General</p>	<p>Due to depth of structure, emptying of stored stormwater would likely require the use of a pumping system. The ability to handle accumulation of sediment deposits and scum should be anticipated after each event. Pavement markings, signs, etc... would need to be scoured clean. Cleaning and proper ventilation of all submerged surfaces to prevent mold and mildew from forming would be necessary.</p>
<p style="text-align: center;">General</p>	<p>System components should take into account redundancy and have backup plans if primary flood risk management components fail or break.</p>
<p style="text-align: center;">General</p>	<p>There would be events through the years that hit the action trigger points requiring evacuation of vehicles but ultimately the event does not end up large enough to require the underground structure to be filled with any stormwater. These trigger events, which cause evacuations yet no filling of the structure, must not sway future operation actions to execute at the set trigger point.</p>
<p style="text-align: center;">General</p>	<p>Inspection, operational testing, and personnel training on flood risk management components should be required at least once every year at a minimum. (Definitely required if system is entered into and approved for the PL84-99 program.)</p>
<p style="text-align: center;">Smithsonian Institution DRAFT EIS South Mall Campus Master Plan</p>	<p>Potential conflicts with 2017 Smithsonian Institution, South Mall Campus Master Plan for the alternatives that call for underground expansion. Specifically the vicinity where the proposed parking structure access ramp connects in-between the underground structure and daylights out towards Independence Avenue.</p>

Table 10: HYDROLOGY

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
General	<p>What are the major concerns and risks? None of the documentation provided addresses how the stormwater would get to the underground facility. In both flood studies (2011 Federal Triangle Study Stormwater Drainage Study; 2007 GSA_DC_Flood_Study_Draft_01232007) it is noted that significant improvements to the existing stormwater infrastructure are needed. The primary cause of the 2006 flooding was that there was too much rain and the size/condition of the existing stormwater pipe network could not handle the runoff. Thus, the pipes get full, water backs up out of inlets/manholes, and water ponds on the roads. If improvements to the stormwater system (pumps to the underground facility or pipe enlargements) do not occur with this project, flooding would continue, because the pipes are not big enough to handle the flow. The underground facility could be designed to handle a 200-year volume of water, but if the pipes are not designed to convey a 200-year flow to that facility, it does not make a difference. To get water to the underground facility and eliminate overland flooding, significant, costly improvements would be needed and are not accounted for in any design/cost/benefit-cost document provided in this document. For example, a pipe currently sized at 12" may need to be enlarged to 36" to accommodate, and it is possible that large tunnels would be required. Not only would mainline pipes need enlarged, but secondary lines as well. The GSA study states that stormwater improvements/pump station could be \$5M-\$10M. The 2011 Federal Triangle Study does not give costs. But, the stormwater system improvements needed to get the water to this underground facility would be very costly (which could change economic analyses) and would disturb traffic in the entire National Mall area for years.</p>
General	<p>What are the major concerns and risks? Developing a plan to evacuate the parking areas to allow for flood storage would be a challenge. The type of storm that this facility is design for is a <i>flash flood</i>. The only "warning" available would be forecast based. Meaning, the NWS would predict a heavy rainfall and it may or may not occur, and when exactly high flows in the underground facility would be expected would be nearly impossible to predict. There would be a significant risk that vehicles would get trapped in the facility, or, on the other end of the spectrum, the facility be evacuated when it wouldn't be needed.</p>
General	<p>What other information is needed and what would be the key recommended steps (analysis) moving forward? An analysis of the stormwater system improvements that would be required to get the water to the underground facility is required. A 1D/2D stormwater model would be required to determine the pipe sizes and/or pump capacity needed to get the water to their underground facility. Once this information is determined, a cost associated with these required improvements can be determined and added to the economic analysis.</p>
General	<p>A design duration of 6-hours is likely not appropriate for a storage solution, the storage solution should consider a duration that is consistent with the pump capacity. For example, if the 6-hour duration is used, then the pump capacity should be capable of discharging the residual rainfall of the 200-year/12-hour storm. Combinations of pump capacity and storage should be developed to optimize the risk reduction efficiency, also incorporating other considerations such as water quality, parking, surface footprint, etc.</p>
General	<p>Confidence of calibrating a complicated model (many parameters) to limited events (primarily 2006) is low. This speaks to the credibility of using the model for predicting the storage/pump requirements of frequency storms.</p>

General	A flood history of interior stages at various points should be compiled to compare to the modeling results and in the development of project benefits and costs.
General	The evacuation plan should have triggers for various conditions to prevent drowning or death/injury from a chaotic evacuation situation , these should be conservative/simple given the uncertainty of human behavior.
Charge Questions: Capacity	28.5-million gallons is approximately 88-acre-feet; which relates to approximately 0.3-inches of runoff for a 5.8-square-mile drainage area. This is a small fraction of the rainfall of even a 6-hour/200-year storm. Although the reviewer appreciates the complexity of the urban drainage system and how a large majority of that contributing area is otherwise managed by the existing infrastructure, a total water budget should be developed to simply understand the water stored in buildings, other underground infrastructure, surface, and conveyed through the existing combined system.
General	The description of the hydrologic model (Greenly and Hansen, 2011) used to develop the frequency design storms illustrates that it is a very complex system, with many parameters and boundaries. The model is really only calibrated to a single event (2006). In addition, it is described that the drainage area itself is a calibration parameter (e.g. 40-percent). Based on this information, I would characterize the confidence in the hydrologic model as low and should be supplemented in order to develop a required storage requirement.
General	A longer duration than 6-hours should be evaluated for a storage solution. Any duration where the existing facilities capacity is exceeded would contribute to the elimination of the underground storage capacity.
General	During flash flooding events that are characteristic of summer thunderstorms, the provided information has not demonstrated that it is reasonable to assume that the vehicles would be evacuated. The cost and environmental impacts of flooded vehicles should therefore be included in consideration of this option.
General	Demonstration that 0.3-inches of basin runoff is sufficient to provide meaningful flood damage reduction to the Federal Triangle. Currently, the evaluation is based on a sophisticated coupling of a hydrologic and hydrodynamic runoff model that is calibrated to a single event (2006).
General	Demonstrate that an evacuation strategy could work for flash flooding scenarios and/or that there are sufficient triggers to ensure the protection of life during a flooding event.
General	Perform table top and mock exercises to evaluate the potential to evacuate vehicles and minimize potential for injury or death.
General	Demonstrate the volume of water contributed to the underground storage and that is otherwise stored on the surface, other underground sources, and otherwise managed.
Ancillary Questions: Can the study area receive water from the existing infrastructure/groundwater?	Based on the reviewed documentation, it is unclear if there is a potential for the required flow/volume of water to minimize flooding from a 200-year event storm event. Based on limited understanding of the overall system and topography, it is likely possible; but with the available information, I cannot provide an opinion on feasibility.

Rainwater and groundwater harvesting? Considering risk of evacuating vehicles?	Based on the reviewed information, it is believed that rainwater harvesting would be limited to smaller events. The major events are a challenge for two reasons: 1. The water would need to be immediately pumped to be available for additional periods of intense rainfall within that event and future events, and 2. The major events would likely flood numerous vehicles and would therefore contaminate the area with volatile organic compounds.
Life safety concerns	As previously mentioned, it has not been demonstrated that vehicles could be safely evacuated. The evacuation process itself could provide an increased risk to life safety above the existing flooding condition.

Table 11: MECHANICAL/ELECTRICAL

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Conceptual Design Sketches and 2011 Federal Triangle Drainage Study	Realizing design is conceptual, but no space is set aside for pump station, controls, or electrical equipment on any of the levels in the sketches supplied.
Conceptual Design Sketches and 2011 Federal Triangle Drainage Study	An evaluation of the reliability of electric power would need to be performed and possibly backup power supplied for pumping and other emergency loads included.
Conceptual Design Sketches and 2011 Federal Triangle Drainage Study	Need sketches with elevations and overall dimensions to evaluate pumping requirements.
General	Assuming there would be a constant need for groundwater pumping. Need to evaluate the volume of that and need for redundancy.
Arthur.pdf and 2011 Federal Triangle Drainage Study	Assuming bottom elevation of garage at -22 and need to pump out garage in 24 hours. 100 yr. flood elevation 12.2 and ~28.5 M gallon reservoir: 20,000 gpm of pumping, 300 hp, 30 inch pipe.
General	Where could water be pumped to? Most direct route seems to be to the tidal basin. Probably would need redundant backflow prevention, e.g. flap valve and slide gate that closes in an emergency, on the discharge pipe.
General	Is the study area suitable for a pump station? I see no technical reasons why a pump station could not be a part of the facility. What makes this unusual, is that it would be a pump station with a ponding area that is normally occupied and would require evacuation prior to being able to be utilized for storage.
General	Is there pumping required to transport floodwaters from north of the study using existing infrastructure? Low point of Constitution Ave. storm sewer is approximately -2, from figure 3-3 in the 2011 flood study. So, water could flow by gravity into parking garage through new connector sewer. This sewer would be gated, probably redundantly in order to mitigate the risk of a gate malfunctioning.
2011 Federal Triangle Drainage Study	Table 4-1 assumes that the Constitution Ave. tide gate remains open until the 10 yr. flood elevation (6.8) in the tidal basin. If this is the case, backflow from the tidal basin would flood Constitution Ave. (low point 4.63) at river stages lower than this. May need to close this gate at a lower river stage when diverting water to the Mall in order to prevent backflow from the tidal basin.

Table 12: CONSTRUCTION

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
Clark's 2 level Design/Bid/Build schedule	Clark's 2 level Design/Bid/Build schedule shows a 773 day duration. It also shows that site setup/grading/dewatering and entry tunnels begin 157 days before notice to proceed (NTP) and end before or right around the issuance of the NTP. A few other activities also begin before NTP. In addition, the schedule does not show the 144 days required for Clark to assemble a shoring and dewatering plan as shown on their Design/Build schedule. The plan must be prepared by Clark and thus would increase the duration of the project. However, some amount of time may be able to be deducted from the 274 days that Clark has assumed for developing bid documents & permitting prior to NTP.
General	Some of the required permits include: 1. NPS Special Use Permit; 2. DC Department of Consumer and Regulatory Affairs Building Permit; 3. DC Sediment Control and Stormwater Management Permits; 4. United States Department of Interior Permit for Archeological Investigations

Table 13: PLANNING

Document Reviewed	Comment
<i>Name of Document Reviewed</i>	<i>Description of Comment</i>
General	Concerned with buses parking on a level that would be flooded during a high flood event. When and who determines when buses can and cannot park there? There is limited flood warning time for this type of interior flooding. This is a major life safety issue to have buses and bus drivers in an area that can be submerged. Would it be closed to buses if heavy rain is predicted? If significant rain starts during the day and it must close, how are bus drivers notified?
General	How much time would it take the buses to evacuate if heavy rain starts during the day? Concerned with bus drivers being trapped in the garage.
General	Where would the buses park on days that the facility is closed if they had planned to park there?
General	How good is the traffic flow out of the garage if it needs to be evacuated quickly?
General	How fast can the flooded level be pumped out and what type of cleaning must be done before the buses can park in the facility? May lose days of revenue after a flood.
General	Would there be health issues in the flood/parking level following a flood event? Mold, bacteria concerns? How would this be handled?
General	Currently the Federal Triangle area stormwater system uses both a gravity storm sewer system and a combined sewer system that takes the flow to pump stations and the WWTP. Part of this project would have to include the construction of a new stormwater collection system. The July 2011 report states that the project cost for Alternative E (storage below Mall) is \$400M. In various documents, the project is estimated to cost \$130-\$230M. Does this cost not include the new stormwater system?
General	What triggers the use of the storage facility? Would stormwater pipes usually take water elsewhere (Blue Plains WWTP), and only if the pipes are filled to a certain capacity would the flow be redirected into the storage facility? Or would the transfer be done manually?
General	There would be major impacts to the Mall during construction; would impact recreation, tourism and special events.
General	Is the National Mall Coalition aware of what exists under the Mall in this area? Are there underground utilities and/or sensitive facilities that would affect the project?
Federal Triangle Stormwater July 2011 Report	Study mentions that NPS does not issue easements, just 10-year right of way permits . Project would need to work through this issue.
Federal Triangle Stormwater July 2011 Report	Study mentions possibility of back to back storm events; project would need to consider how fast facility can be pumped out -before another flood event, or for bus parking.

Federal Triangle Stormwater July 2011 Report	Study mentions that irrigation water would need to be treated for bacteria; has this been incorporated into the project and cost?
Federal Triangle Stormwater July 2011 Report	Study also mentions top of storage facility would need to be at least 8 feet below grade ; has this been incorporated into project and cost?
Dewberry Feasibility Study	This study estimates project cost of \$60M to provide 1,000 parking spaces to justify cost effectiveness ; project would likely cost much more and less parking would be provided
General	Question: How was evacuation handled during the 2011 storm event? Could provide some important insight.
General	Groundwater elevation- topography (DC OCTO)
General	Evacuation is a major concern. With unpredictability of flashy storms, would probably be beneficial to create a system that would not require evacuation.
2011 Flood Study	Seems like there would have to be a massive effort put forth in redesigning the stormwater network, because it is currently sized for a 15-year storm event. Fed. Triangle area would have to have even larger pipes, depending on the sizing of pipes .
Clark Construction Costs	Why is the cost showing as half the amount estimated in the flood study?
Dewberry #1	Exhibit C states that you could provide approx. 2 levels before a depth of elevation 0 (sea level). Existing steam tunnels, irrigation systems, and other supporting utilities would need to be relocated outside of the garage footprint.
Dewberry # 2	Width of 180' allows for three rows of parking. Ceiling height of 12-ft. as a minimum height? (Assuming a depth of 5-ft to 6-ft above the ceiling that would be used for structure and planting.)
Dewberry Water Budget	Identifies a total average irrigation demand water budget for ALL panels as being 28 M gallons.
PES Anita	Costs range between \$124-\$135 million?
PES Anita	Two levels - \$168.7 M, 3 levels \$234.3. M
South Mall EIS	Overlap issues with tunnel entrance?

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APPENDIX D:
CHARRETTE NOTES

DC National Mall Underground Charrette Meeting Notes: 3/5/2018

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Funding and background info:

- Judy Feldman-
 - Most recent financials were completed in 2014
 - Army Navy Club (Albert Small)
 - Jim Pickman- Underground Parking in Philadelphia (Independence Mall)
 - Wall Street Advisors (Decided that this would be something that could be funded because of potential revenue generation and stormwater credits)
 - Potential for incorporation of geothermal energy generation
 - Smithsonian liked the idea of a parking structure
 - Bob Vogel was talking about changing the National Mall Plan
 - Hours of operation: Parking would not be open until 10 AM (only for tourism), open every day and closes at 11 PM (?)
 - In 2011 area received around 14" over a 3 day span

Flash Flooding:

- Arthur Moore-
 - Flooding would only be stored in the lowest floor
 - Lower level would not have humans in the new concept (with automated parking in the bottom level)
 - Buses on lower level ~400 buses
 - Dormitory where bus drivers could be close to the buses in case of emergency
 - Bus drivers would have to stay there (as part of their contract (?))
 - Bus drivers could sleep, eat and shower in the dormitory
 - There would be cisterns that could be evacuated
- Judy Feldman-
 - Flooding for Federal Triangle happened over three days.
 - USACE H&H-
 - Intense rainfall happened over a short period of time during the 3 days, so it is considered flashy

Trigger Points and Operational Risk Assessment:

- USACE Civil-
 - Operational risk assessment: using Monte Carlo simulations can show the risk and how the garage could potentially operate. Factors could include, and are not limited to:
 - Insurance
 - Cisterns
 - When to close off areas of the garage to start to flood
 - When to start evacuations (?)
 - Trigger points:
 - To evacuate. To trigger cut-off valves
 - Redundancy:
 - If the system goes down. What is the back-up plan?
 - Stand by generators
- Arthur Moore-
 - Water would potentially fill segmented areas

Flood Capacity, Inflow, and Outflow in Underground Storage:

- Arthur Moore-
 - Report requires 24 M gallons and the garage would hold 28 M
- USACE H&H-
 - Make sure volume is storage reliable (able to recover for frequent storms)
 - Assumed 6-hour duration might be sufficient
 - May be a potential for making the garage deeper to increase storage volume
- USACE Civil-
 - Control inflow through gates or pumps
 - Someone may need to manually decide

Other Project Examples:

Washington Harbor:

- USACE Structural-
 - Washington Harbor is riverine/coastal flooding- would have more time for evacuation, pre-flood actions, etc.
 - There is a gauge at Harper's Ferry to give ample warning time (about 30 hrs.)
 - Is there elevator access in the bottom, floodable level?
 - Arthur Moore Response: No
 - 49 schemes were drawn up to figure out the weight that the building needed to be in order to counter the uplift forces
 - There is a sump for pumping out water
 - There are issues with sediment deposit
 - USACE Planning-
 - Do people park in the lower level?
 - Arthur Moore- Yes

World War 2 Memorial and African American Museum

- USACE Geotech-
 - Slurry wall was used at both of these sites

Other Projects:

- Philadelphia Independence Mall Underground Parking Garage
- Millennium Park
- Washington Cathedral
- Chicago
- Kuala Lumpur

Data on surrounding areas:

- USACE Geotech-
 - Potential for data on soil to be recovered from USGS
- Arthur Moore-
 - Need to get more information from surrounding buildings
 - Looking for USACE support in obtaining this information from surrounding entities
- USACE H&H-
 - Are there surrounding utilities?
 - Judy Feldman-

- Dewberry mentioned that there was nothing of massive significance there, but needs to be confirmed.
- USACE Construction-
 - During 17th Street closure construction there was a secret conduit discovered.

Constructability and Discussions with Engineer Consultant:

Sheet Piling vs Slurry Wall vs Secant Wall:

- Arthur Moore-
 - Looking at conventional sheet piling
- Consultant Engineer-
 - Would likely need sheet piles to prevent uplift
 - Another option is a thick matt slab to weigh down the structure
 - There are some boring of surrounding project sites, including 9th and 12th Street tunnels
 - Bedrock drops down about 150 ft.

Two major items missing:

- Design groundwater table
- Geotechnical data

Groundwater:

- Engineering Consultant-
 - Sustained groundwater table

Geotechnical Data:

- Engineering Consultant-
 - Need for refined data
 - Rock goes about 150 ft. down
 - There may be some retention cells throughout the project area
 - Could get information from surrounding projects as well
- USACE Geotech-
 - Need to perform site exploration and incorporate this into costs
 - Only ~\$50K accounted for in the cost information provided by Clark Construction
 - USGS has data online

Super Structure:

- Consultant Engineer-
 - Looking at a structure that can house a mechanical system
 - Precast bearing walls
 - Similar to McMillan plant
 - Unreinforced concrete with saturated elements
 - Potential need for open steel frame structure

Current Parking Rules around the National Mall:

- USACE Structural-
 - Are there Ordinances for the bus parking on the streets?
 - Arthur Moore- Yes.
 - But they are not really enforced. The idea is to provide a viable alternative so that the current parking rules can actually be enforced.

- MWCOG stated that the Underground is the best solution for air quality and parking demand.

Security:

- Arthur Moore-
 - Buses and cars would go through a screening area.
 - People would be offloaded at the screening area.

Life Safety and Evacuation of Buses:

- Arthur Moore-
 - Lower level would not have humans for the new concept (with automated parking in the bottom level)
 - Working with Navy to have an all magnetic system
 - Would be submersible
 - All buses would be moved automatically
 - USACE H&H-
 - How much time would it take to move 1 bus?
 - This idea could potentially be better because there are no humans in the bottom level
 - USACE Civil-
 - Concerned with maintenance requirements
 - USACE Planning-
 - Potential health issues with left over silt and toxic debris
 - Current Concept requires humans to drive buses out during a flood
 - USACE H&H:
 - Did you perform a survey of bus drivers to see if they would stay near their vehicles?
 - Judy Feldman and Arthur Moore:
 - This would be a contractual requirement
 - American Bus Association likes this idea

Stormwater Infrastructure and Modeling:

- USACE H&H-
 - How are you getting water to the system?
 - The entire system would require upgrading and this could be very expensive
 - Arthur Moore:
 - Government would ideally cover this portion
 - Government originally proposed dykes to push water to Pennsylvania Avenue
 - Would be good to see DC Water modeling
- USACE H&H-
 - This is a relatively small amount of volume
 - Sophisticated modeling required, the model for the 2011 study was only calibrated against the 2006 model
 - Should be looking at different events and frequencies to get more confidence.
- Judy Feldman-
 - There is a sewer under Constitution Avenue

- Trying to figure out from DC Water and see who is responsible for it.

Construction Timeline:

- USACE Construction-
 - Construction timeline should be revisited because certain features may not have enough time built into them.
 - Need to consider a variety of permits

Pumping:

- USACE Electrical/Mechanical-
 - May need submersible pumps
 - Controls on the upper levels

Where would water be pumped to?

- Arthur Moore-
 - Potential for controlled release to Blue Plains WTP
 - Acquire a piece of land and create a small mound to house linear wetlands to clean water
 - Water could be cleaned to levels of water quality comparable to the Potomac River
 - Would not be able to pump directly into the tidal basin without treatment

Costs:

- Arthur Moore-
 - Pumping not included in the budget

Project Drivers, Costs, and Economic Benefits:

- Arthur Moore-
 - 3rd floor adds a lot of bus parking and revenue
 - Additional benefits
 - Potable water purchasing (can provide grey water), can potentially sell to park service
 - Water quality treatment
- Judy Feldman-
 - Key that the structure is multi-purpose
 - Should we present multiple options?
 - One to minimize revenue/parking
 - One to reduce flooding
 - All-
 - Could be a good idea to do so
 - Need to refine costs to be able to set up an Econ. Assessment

Cleanup and Maintenance:

- USACE Structural-
 - Silt and grit needs to be cleaned up after a storm. Could be expensive
 - Arthur Moore-
 - There is current cleanup efforts at Washington Harbor, and there is more sediment deposit in that situation.
 - USACE Planning-
 - Potential health issues with left over silt and toxic debris

- Ventilation would be required

Rain Water and Groundwater Harvesting:

- USACE H&H-
 - Have to clear out cisterns right away if they are providing storage for the overall system
 - May have to retain water to function for irrigation but need to have space for emergency flood storage.

APPENDIX E:
NATIONAL MALL UNDERGROUND OPERATIONAL RISK:
PROTOCOL AND STAGING OF FLOODWATERS,
COALITION CHARRETTE RESPONSE

National Mall Underground Operational Risk
Protocol and Staging of Floodwaters

National Mall Coalition
March 30, 2018

During the Army Corps' March 5th charrette with the National Mall Coalition to discuss the Corps' technical evaluation of the proposed the National Mall Underground stormwater retention facility, questions were raised about how the garage could be operated to minimize risk to visitors and vehicles to the facility. While during the session project architect Arthur Moore made reference to an automated facility in which the lower level would have no human presence, Mr. Moore also is still working on the earlier alternative in which bus drivers would accompany the buses to the lower level and thus be subject to risk. The following is a proposed solution to the risk factor for both options.

The 2006 Federal Triangle stormwater flooding event was caused by three days of intensive rain that overloaded the existing sewer system and inundated the streets and buildings on low-lying Constitution Avenue, which is a natural rainfall collector because it is built on top of what was once Tiber Creek. According to the 2011 Federal Triangle Stormwater Flooding Drainage Study, such stormwater flooding events could increase in future, both in number and intensity. Some may be predictable, others not. Given the uncertainty in predicting such flash-flood events, there is a need to establish protocols and procedures to minimize risk.

The Coalition proposes the following protocols to minimize risk:

- Emergency alert system coordinated with the National Weather Service to identify weather events that might cause heavy rainfall and stormwater flooding in the Federal Triangle Area
- Closure of the lower bus level of the facility 12-24 hours before anticipated heavy rain and flooding
- In case of unanticipated flash-flooding, emergency notification via text, Twitter, and so on to bus drivers and others of the need to evacuate the facility, while staged intake of floodwater takes place as described below

Project architect Arthur Cotton Moore proposes design modifications to allow gradual floodwater intake and so minimize risk from flash-flooding, including:

- Use of the groundwater cistern at the west end of the garage, the larger of the two cisterns, to receive first stage stormwater during evacuation of the garage
- Deployment of raisable aluminum panel floodwalls within the garage to create staged floodwater intake to five compartments to allow safe evacuation of all the floodable areas
- Standby generators if system goes down

The attached PowerPoint illustrates the new staging of floodwater intake in the groundwater cistern and into the garage with deployment of the floodwalls. More details below.

The proposed sequence of loading the Underground facility with floodwaters is:

1. Stormwater will be diverted first to the larger ground water cistern, which is designed both to accommodate groundwater and to receive early substantial rainfall. Check valves will ensure that this cistern is never more than half full of groundwater. Using this cistern as the first stage response to flooding will allow time for buses to be removed from the first of the five compartments in the lower level of the garage facility
2. The second step involves taking floodwater into the first garage compartment, which will be isolated from the other four compartments by 8-foot-high aluminum flood panels. This floodwall, normally recessed into the base floor slab, will be raised by winches mounted on the underside of the first-floor slab. The filling of the first compartment will allow controlled intake of floodwater while buses are being evacuated from the other four compartments. This floodwall and winch system has been used repeatedly and successfully at Washington Harbour.
3. As the floodwaters continue to rise, the same procedure will be followed for each of the remaining four compartments. The flood panels will be raised in the second compartment and the waters will be introduced there, then the third compartment, and so on, allowing time for the orderly evacuation of the buses and other vehicles.
4. Once the five compartments are filled and the pressures equalized, the entire lower floor water level will be allowed to rise until it reaches a depth of 15 feet, or one foot lower than the underside of the upper floor slab, in order to protect the lights and the winches.

At a depth of 15 feet the Underground facility will have retained approximately 30 million gallons of floodwater, or more than 6 million gallons in excess of the projected 24-million-gallon 200-year flood as indicated in the 2011 report.

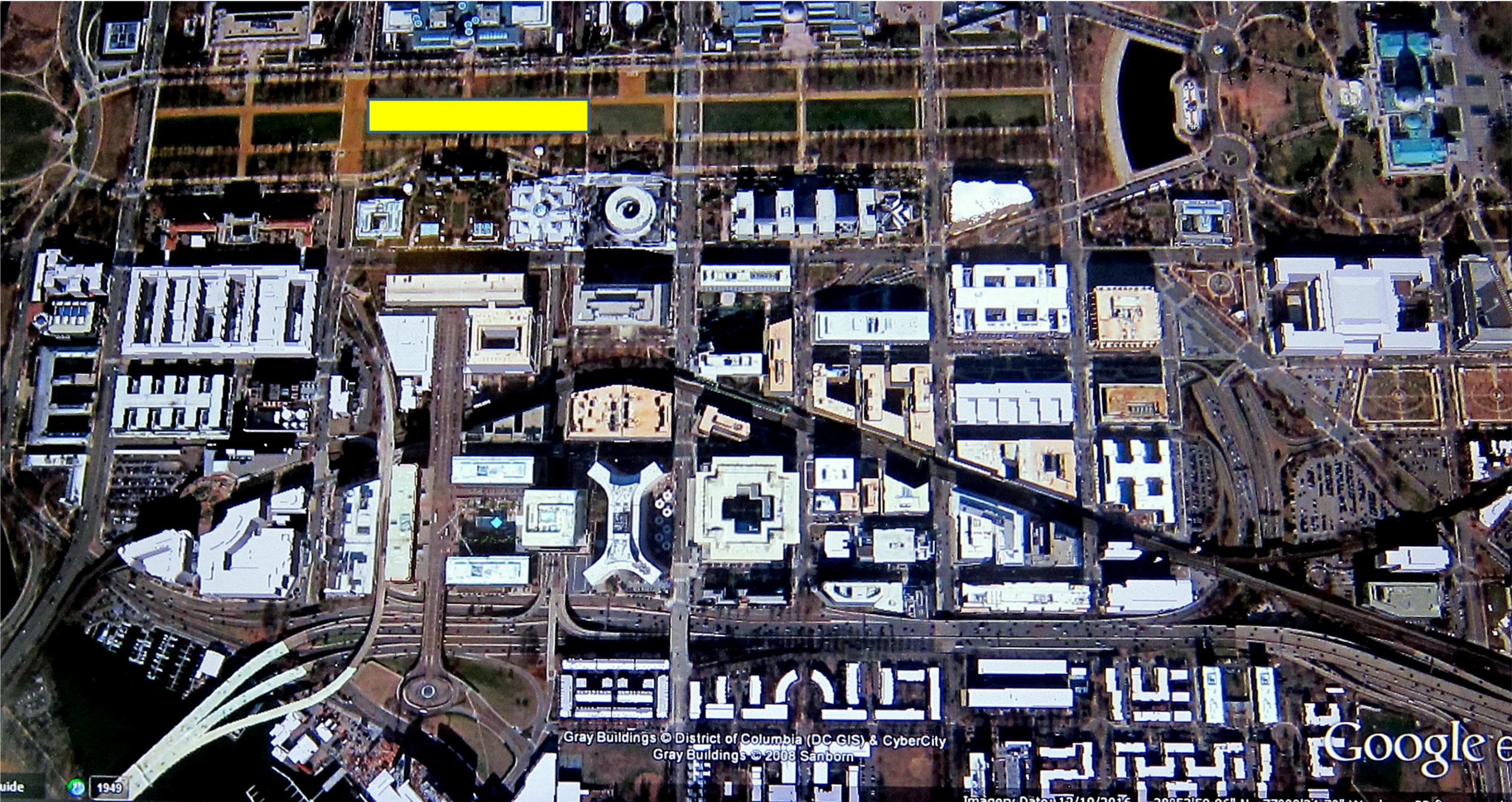
The disposal of the retained floodwater would follow the above sequence in reverse after the storm and after assurance of the present sewer system capacity.

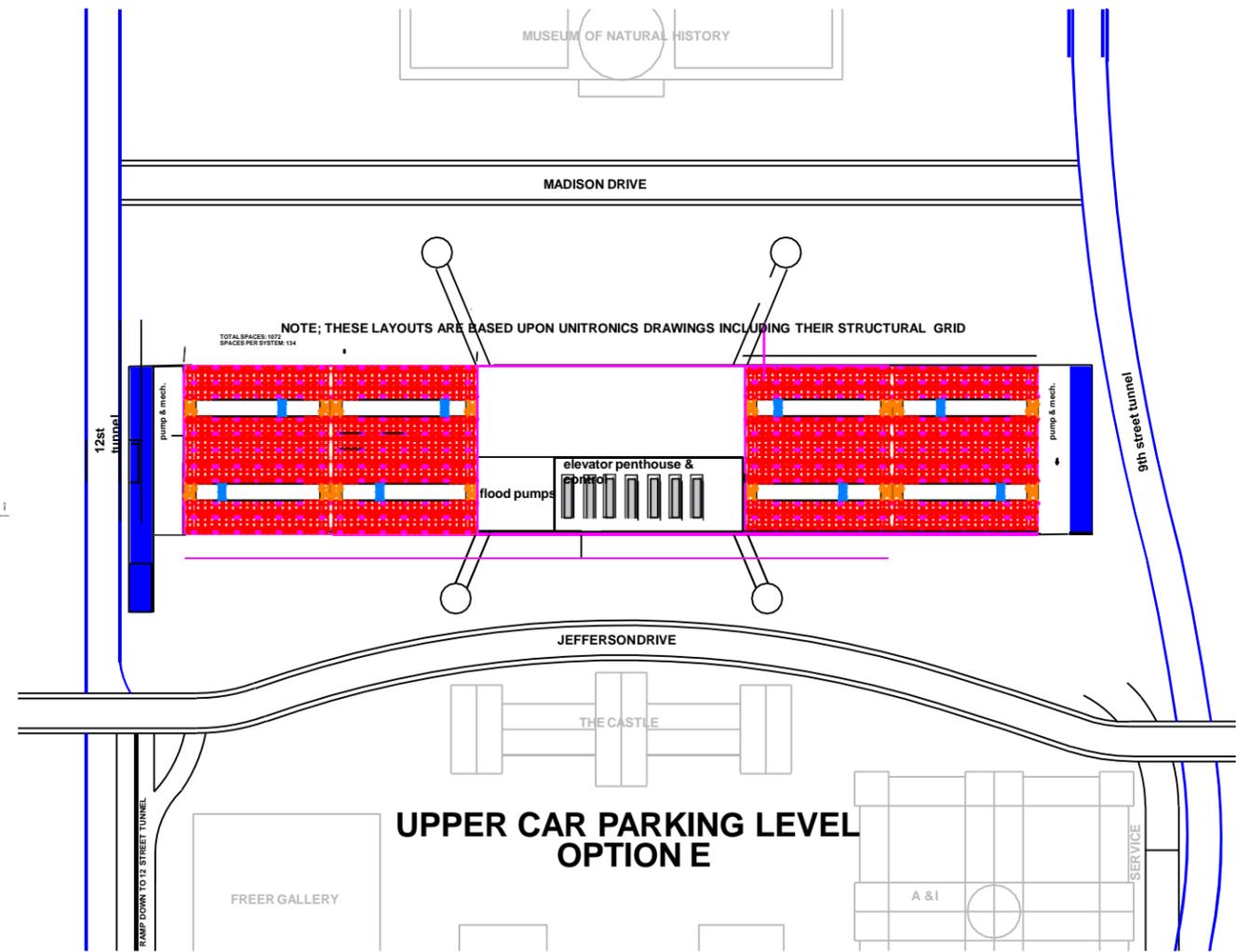
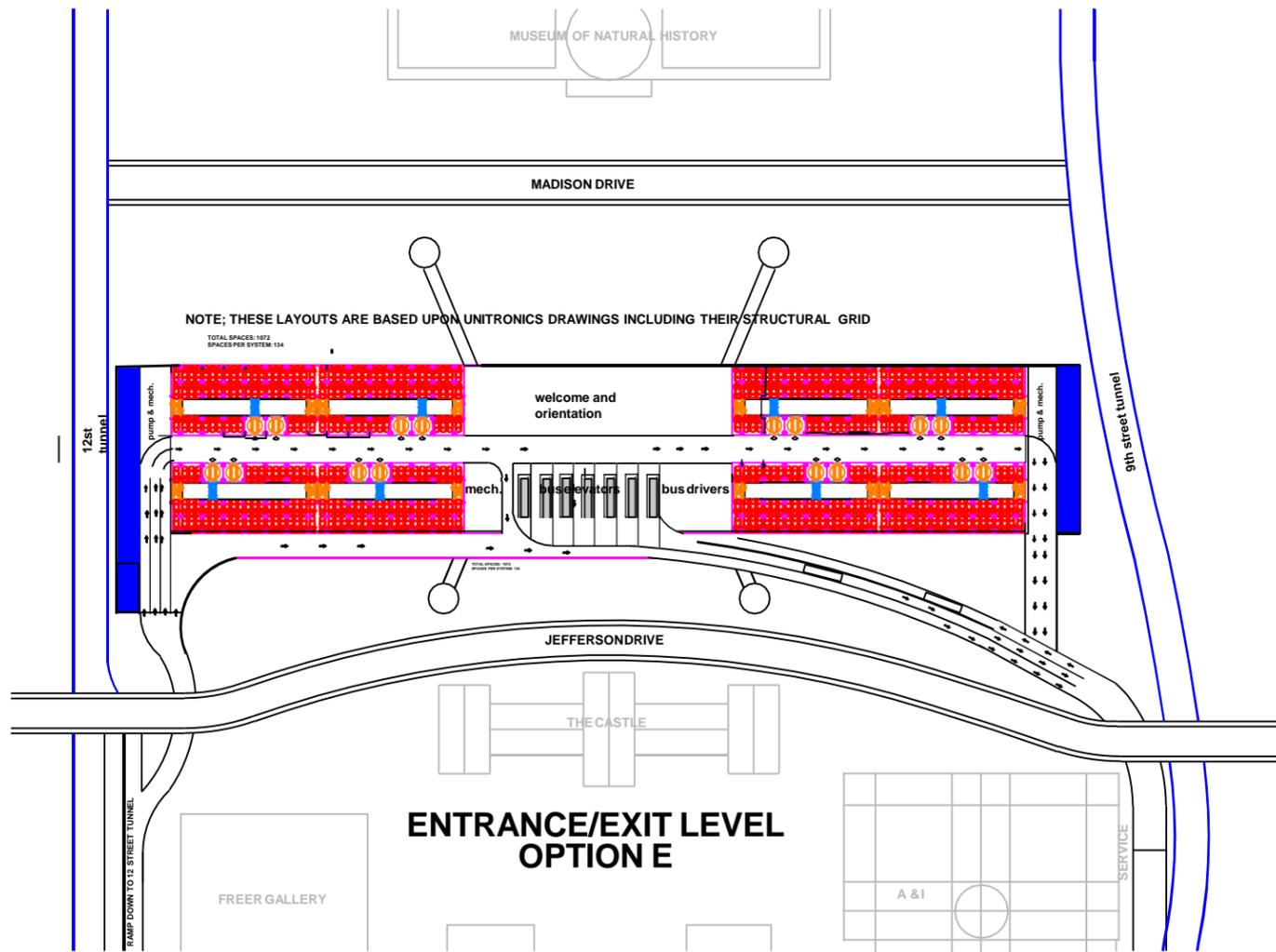
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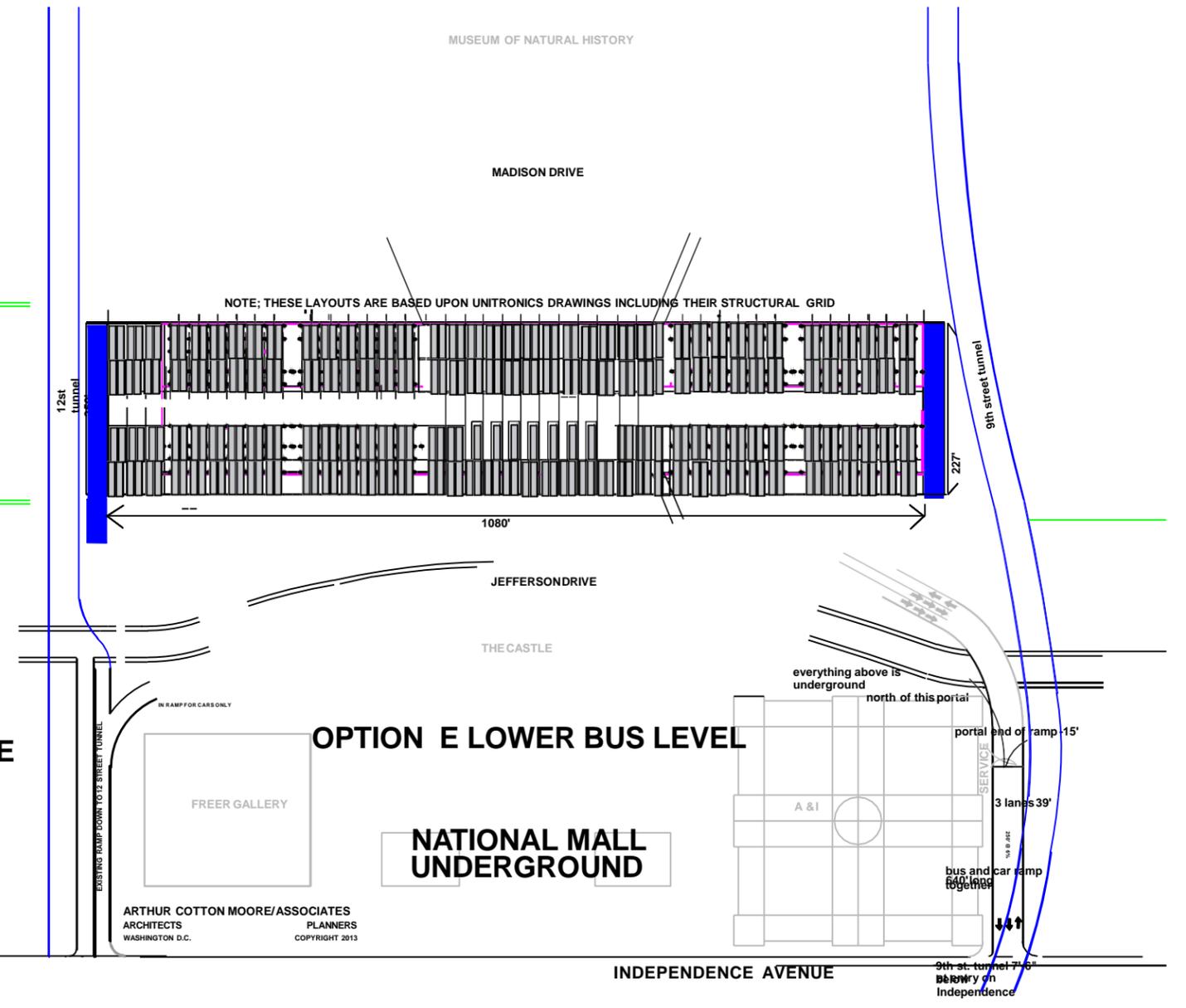
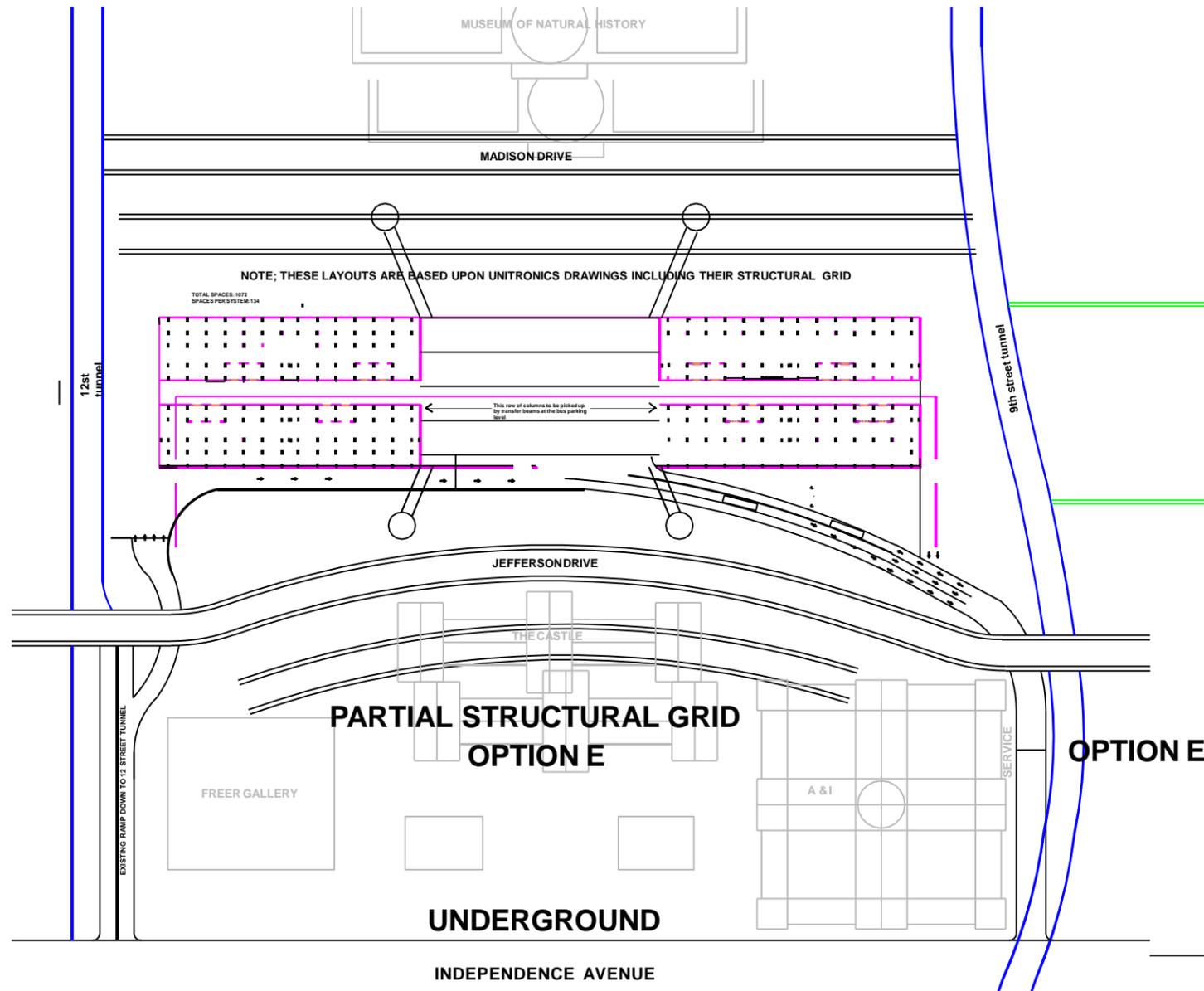
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Judy Scott Feldman 301-340-3938 jfeldman@nationalmallcoalition.org

OPTION E Flood Control and parking based on Robotic Systems







Phasing of the loading of flood waters into the lower bus level

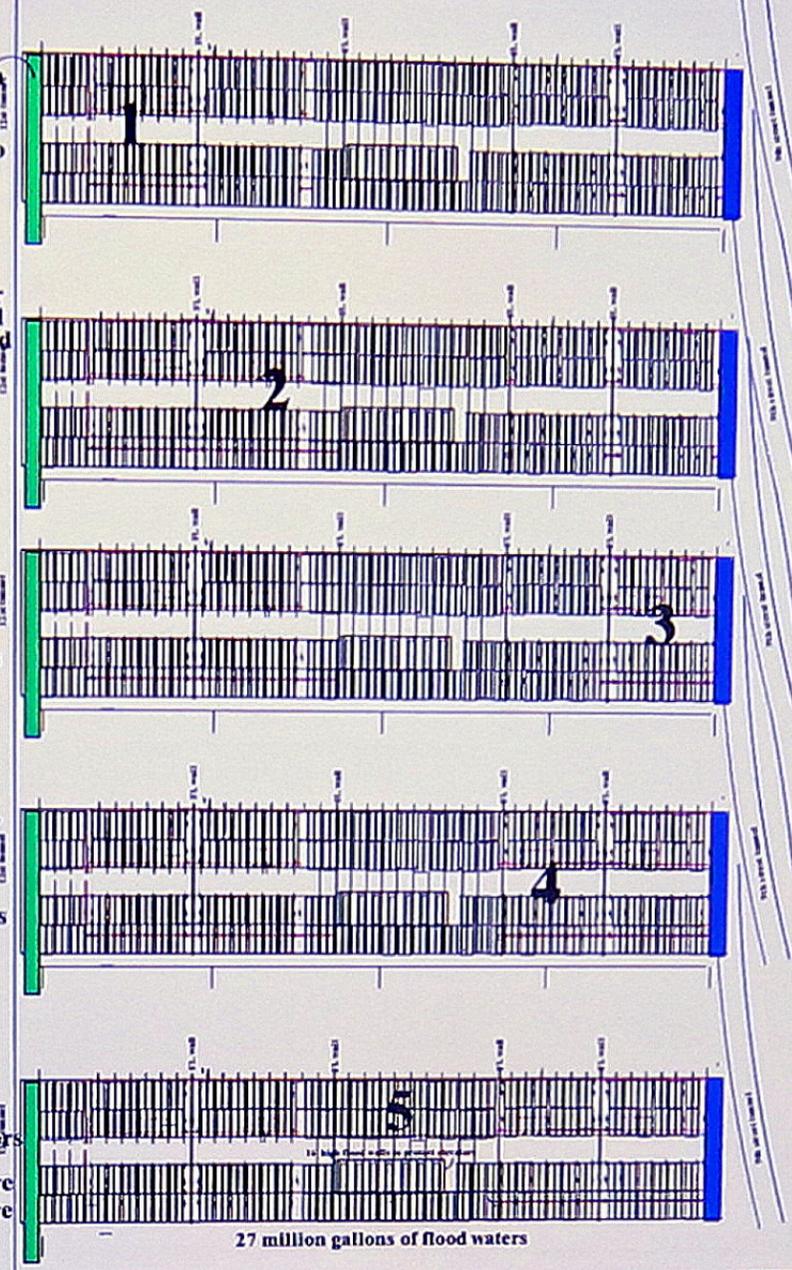
Phase 1 fill ground water cistern while filling remove first sector of buses and raise first internal row of flood walls and begin to fill with flood waters to a height of 6'

Phase 2 remove second sector of buses and raise second internal row of internal flood walls and begin to fill up to height of 6'

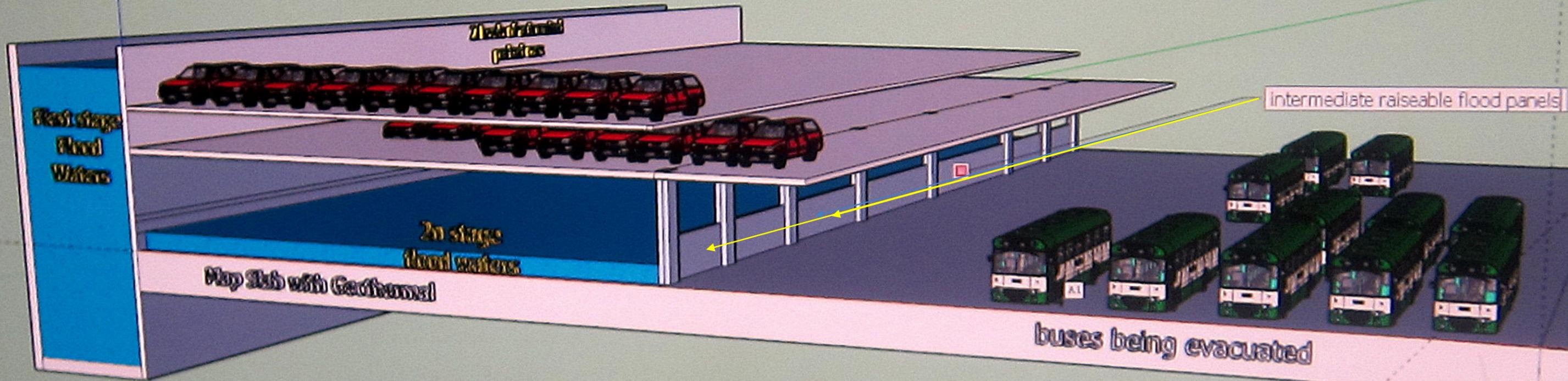
Phase 3 remove third sector of buses and raise third row of internal flood walls and begin to fill up to height of 6' third sector with flood waters

Phase 4 remove fourth sector of buses and raise fourth internal row of flood walls and begin to fill up to height of 6' fourth sector with flood waters

Phase 5 remove fifth sector of buses and raise internal flood walls around bus elevators and begin to fill up to height of 6' in the fifth sector. Once all sectors are equalized continue filling entire floor to a height of 15.5 feet



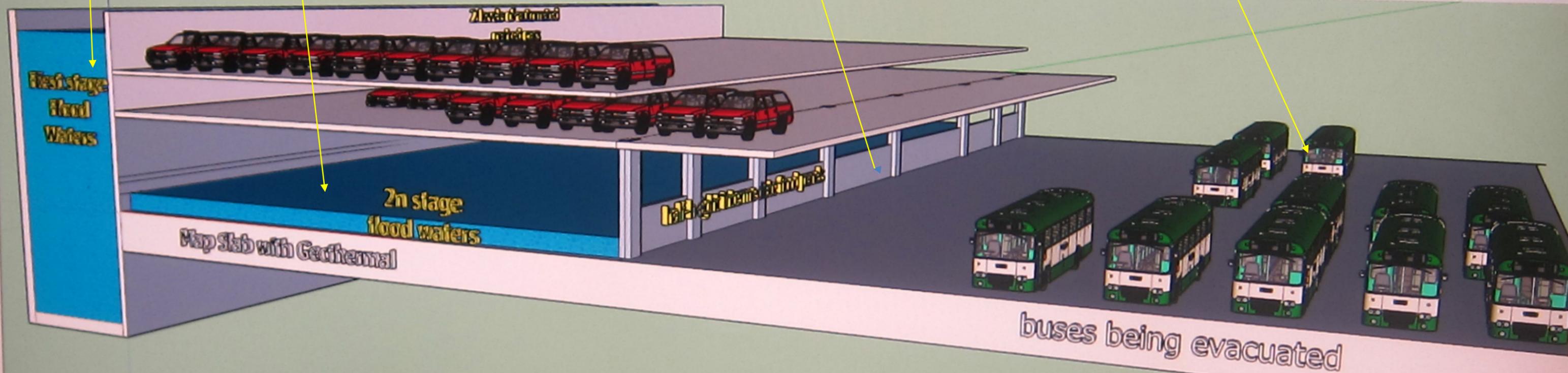
27 million gallons of flood waters



Stage one fill ground water cistern

Stage Two filling of phase one to 6 feet
And raising of intermediate flood panels after evacuation of buses

Stage 3rd begin evacuation of buses





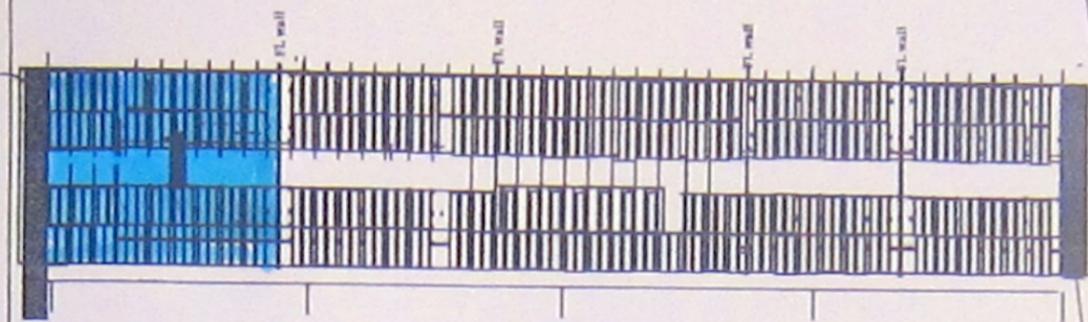
NO
MOORING
MIDNIGHT
TO
6:00 AM



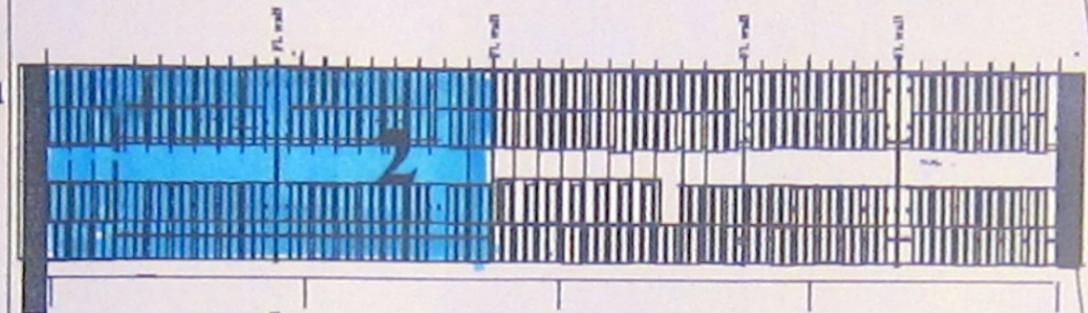


Phasing of the loading of flood waters into the lower bus level

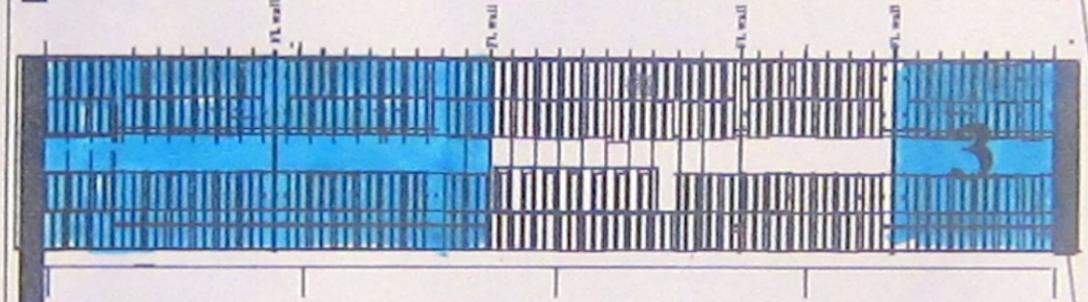
Phase 1 fill ground water cistern while filling remove first sector of buses and raise first internal row of flood walls and begin to fill with flood waters to a height of 6'



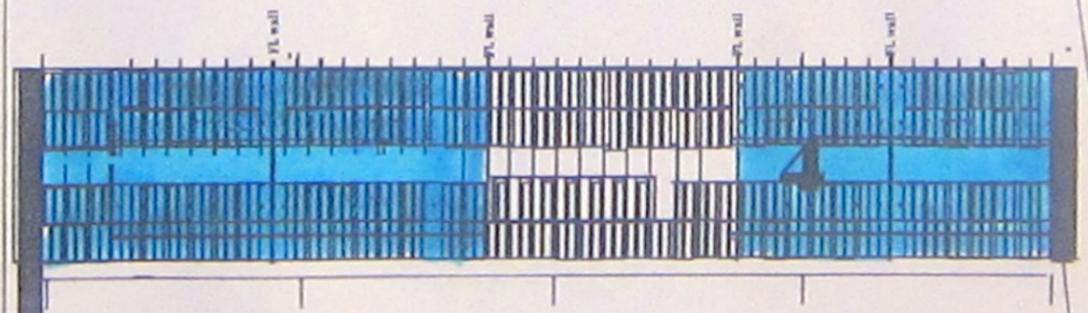
Phase 2 remove second sector of buses and raise second internal row of internal flood walls and begin to fill up to height of 6'



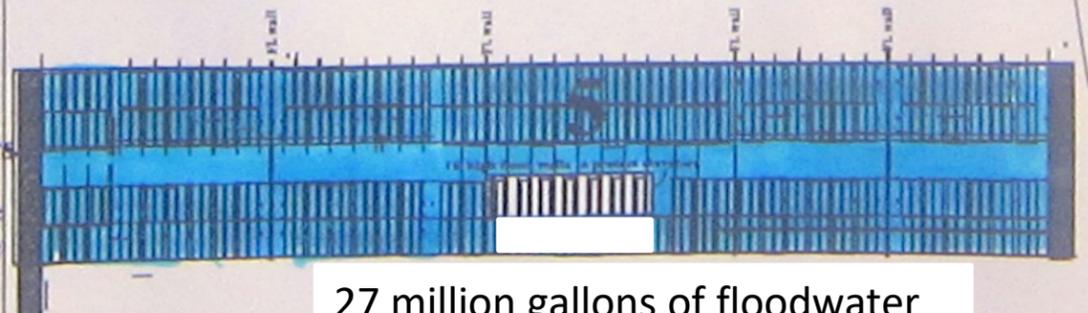
Phase 3 remove third sector of buses and raise third row of internal flood walls and begin to fill up to height of 6' third sector with flood waters



Phase 4 remove fourth sector of buses and raise fourth internal row of flood walls and begin to fill up to height of 6' fourth sector with flood waters

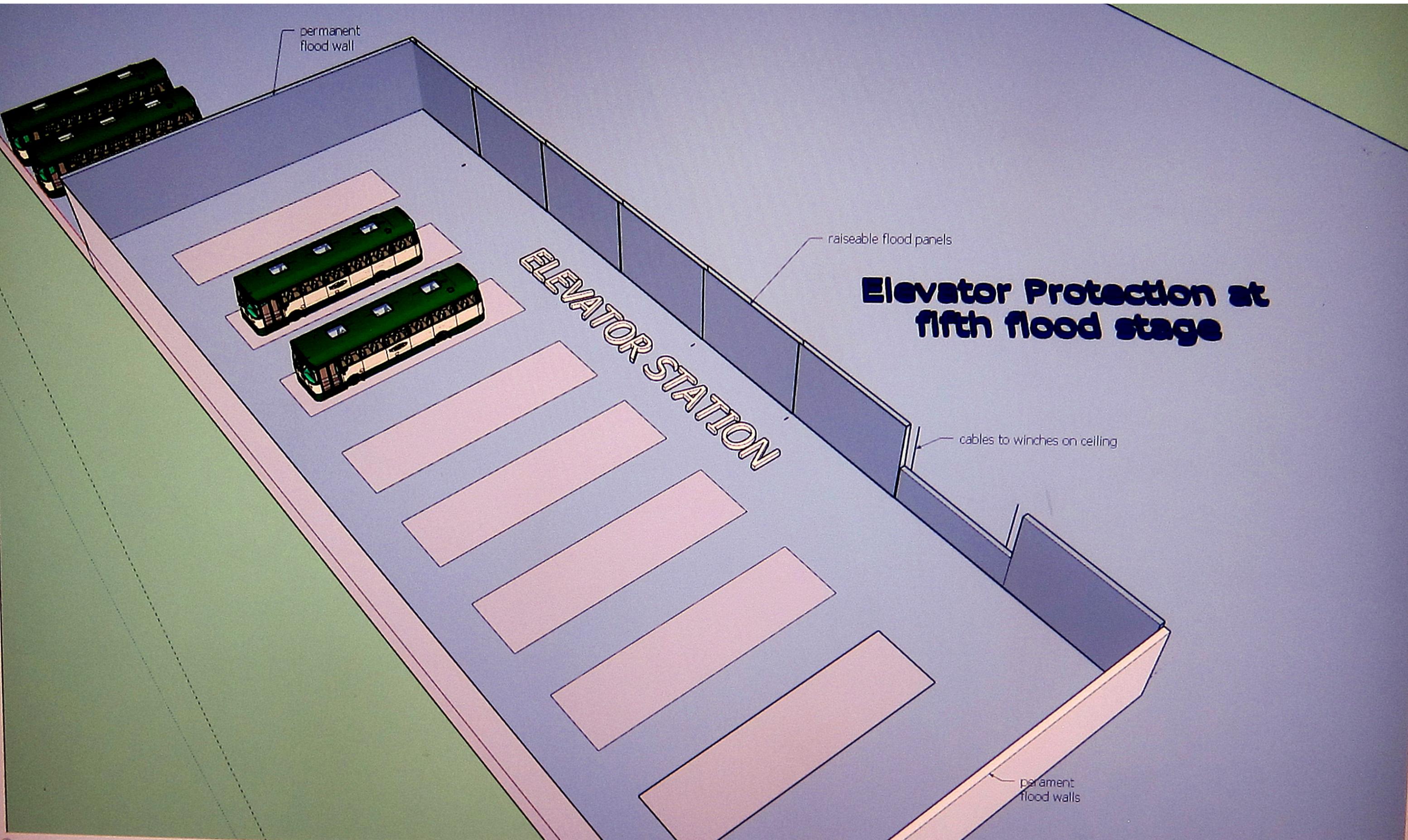


Phase 5 remove fifth sector of buses and raise internal flood walls around bus elevators and begin to fill up to height of 6' in the fifth sector. Once all sectors are equalized continue filling entire floor to a height of 15.5 feet



27 million gallons of floodwater

914 street tunnel
914 street tunnel
914 street tunnel
914 street tunnel
914 street tunnel



permanent
flood wall

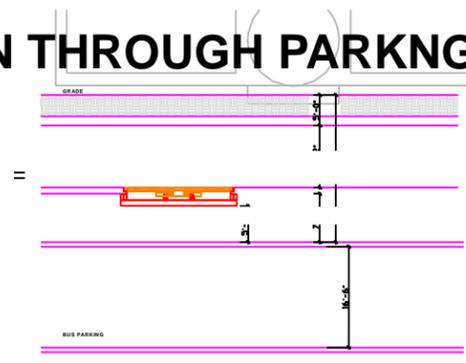
raiseable flood panels

Elevator Protection at fifth flood stage

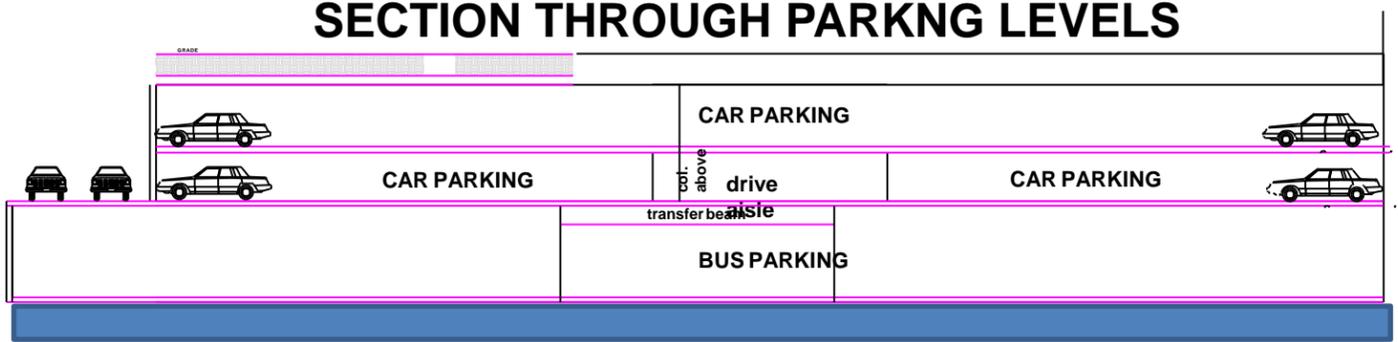
cables to winches on ceiling

permanent
flood walls

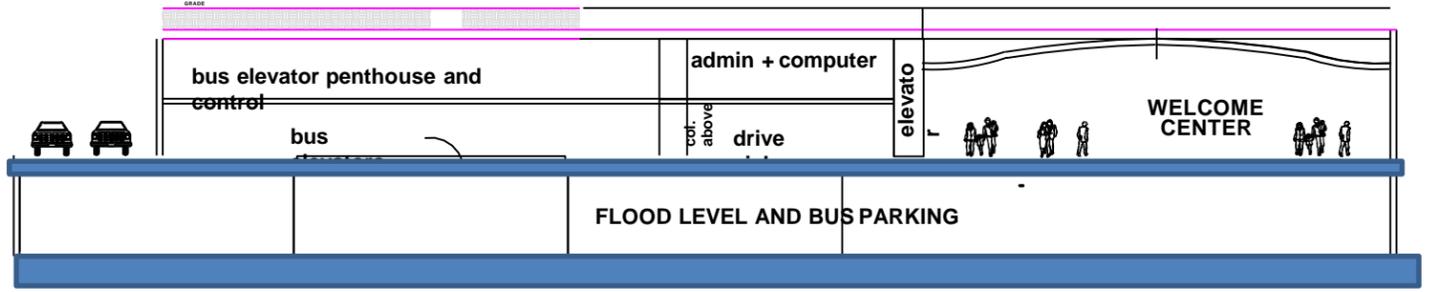
SECTION THROUGH PARKNG LEVELS



SECTION THROUGH PARKNG LEVELS



SECTION THROUGH ORIENTATION WELCOME CENTER



Option E Sections

Phasing of the loading of flood waters into the lower bus level

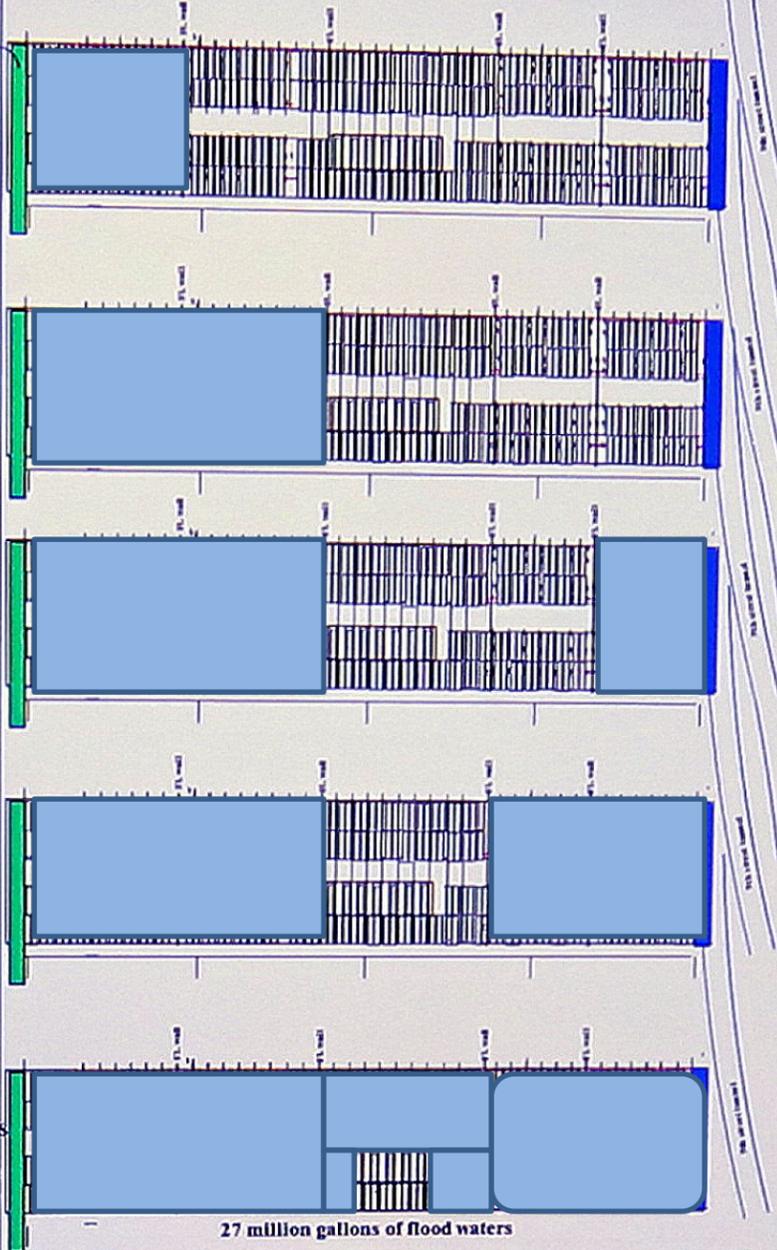
Phase 1 fill ground water cistern while filling remove first sector of buses and raise first internal row of flood walls and begin to fill with flood waters to a height of 6'

Phase 2 remove second sector of buses and raise second internal row of internal flood walls and begin to fill up to height of 6'

Phase 3 remove third sector of buses and raise third row of internal flood walls and begin to fill up to height of 6' third sector with flood waters

Phase 4 remove fourth sector of buses and raise fourth internal row of flood walls and begin to fill up to height of 6' fourth sector with flood waters

Phase 5 remove fifth sector of buses and raise internal flood walls around bus elevators and begin to fill up to height of 6' in the fifth sector. Once all sectors are equalized continue filling entire floor to a height of 15.5 feet



Alternate Phasing Diagram