INTERNATIONAL BOUNDARY AND WATER COMMISSION
UNITED STATES AND MEXICO

El Paso, Texas
MINUTE NO. 332 **December 10, 2024**

CONSTRUCTION OF A COMPOSITE CUTOFF WALL TO REDUCE THE RISK OF FAILURE AT AMISTAD INTERNATIONAL DAM

The Commission met at the United States Section Headquarters Office in El Paso, Texas at 3:30 p.m. on December 10, 2024 to review the conclusions and recommendations developed by the Principal Engineers based on those presented by the Technical Advisors from the United States and Mexico, regarding structural safety measures that must be implemented to reduce the risk of failure at Amistad International Dam due to the presence of sinkholes and seepage.

The Commissioners referred to Article 5 of the "United States-Mexico Treaty for Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande," dated February 3, 1944, which stipulates, "The cost of construction, operation and maintenance of each of the international storage dams shall be prorated between the two Governments in proportion to the capacity allotted to each country for conservation purposes in the reservoir at such dam."

The Commissioners also observed that in Resolution 2(b) of Commission Minute 210, entitled "Recommendations Regarding Construction of Amistad Dam," signed January 12, 1961, the Governments of the United States and Mexico agreed that the distribution of the cost of construction of Amistad International Dam would be made based on the proportions "...56.2 per cent to the United States and 43.8 per cent to Mexico..."

The Commissioners also referred to Commission Minute 235, entitled "Division of Operation and Maintenance Costs of Amistad Dam," signed December 3, 1969, taking note that the "Joint Report of the Principal Engineers Concerning the Division of Operation and Maintenance Costs of Amistad Dam," signed December 1, 1969, which forms an integral part of that Minute, stipulates: "Should it become necessary to perform operation, maintenance, or repair work of an extraordinary or emergency nature which, if not performed promptly might result in risk of serious damage to the project, or in increased cost of its performance, the Commission shall order those works executed which it finds advisable and shall allocate them between the two countries for their performance as soon as possible, understanding that the performance by each Government of the work allotted to it, cannot be undertaken until it has made the necessary financing arrangements therefor."

Furthermore, the Commissioners reviewed and found satisfactory the "Joint Report of the Principal Engineers on the Implementation of Corrective Measures to Reduce the Risk of Failure at Amistad Dam through the Construction of a Composite

Cutoff Wall," signed October 8, 2024 by Principal Engineers Ramon Macias III and Agustín Boone González of the U.S. and Mexican Sections, respectively. In the cited report, the Principal Engineers described the prior studies and research on the structural and functional safety of Amistad International Dam conducted by the two countries' Technical Advisors, which include personnel from the U.S. Army Corps of Engineers and Mexico's National Water Commission. The Principal Engineers also described the proposed structural safety modification project, which consists of reinforcing Amistad Dam's earthen embankment by constructing a Composite Cutoff Wall of 2.6 kilometers (km) in length, which will be located on the Mexican side of the dam embankment, between Stations km 5+393 and 8+000, the area where the greatest number of sinkholes and seepage identified to date are concentrated.

The Commissioners concurred that due to the magnitude of said project, it should be carried out by means of two contracting processes: 1) contracting for the project design; and 2) contracting for the construction of the works.

The Commissioners considered it appropriate that the distribution of costs between the two countries to fund the aforementioned project should be carried out in the same proportion that was used in the construction works for Amistad Dam, under the framework of Commission Minute 210: 56.2% for the United States and 43.8% for Mexico.

The Commissioners observed that both Sections should make the needed arrangements to obtain the funds necessary to cover the costs of the project, and, since it will be undertaken in Mexico, said country, through the Mexican Section of the Commission, should manage the necessary procurement and contracting processes for its design and construction, and the United States, through the U.S. Section of the Commission, should reimburse Mexico for its corresponding amount.

Based on the above, the Commissioners adopted the following Resolutions, subject to the approval of the two Governments:

1. The "Joint Report of the Principal Engineers on the Implementation of Corrective Measures to Reduce the Risk of Failure at Amistad Dam through the Construction of a Composite Cutoff Wall," signed October 8, 2024 by Principal Engineers Ramon Macias III and Agustín Boone González of the U.S. and Mexican Sections, respectively, which forms an integral part of this Minute, is approved.

2. The recommendations of the Principal Engineers in their Joint Report are approved for the execution of the design and construction works of

the Composite Cutoff Wall on the Mexican side of Amistad Dam's earthen embankment.

3. In accordance with the provisions of Commission Minute 235, the works for the construction of the Composite Cutoff Wall on the Mexican side of Amistad Dam's earthen embankment are declared to be of an extraordinary or emergency nature.

4. The distribution of the total cost of the Composite Cutoff Wall project shall be carried out in the same proportion established in Commission Minute 210: 56.2% for the United States and 43.8% for Mexico. Both Sections of the Commission shall make arrangements to request the necessary funds in their respective countries to cover the costs of the project.

5. All activities undertaken pursuant to this Minute shall be subject to the availability of funds, resources, and corresponding personnel in each country.

6. This Minute shall enter into force upon the date of the later notification in an exchange of notifications between the Sections of the Commission confirming approval of this Minute by their respective Governments.

The meeting was adjourned.

Maria-Elena Giner
United States Commissioner

Adriana Beatriz Carolina Reséndez Maldonado
Mexican Commissioner

Sally E. Spener
United States Section Secretary

Manuel Alejandro Morales Galván
Mexican Section Secretary

INTERNATIONAL BOUNDARY AND WATER COMMISSION
UNITED STATES AND MEXICO

El Paso, Texas
October 8, 2024

JOINT REPORT OF THE PRINCIPAL ENGINEERS ON THE IMPLEMENTATION OF CORRECTIVE MEASURES TO REDUCE THE RISK OF FAILURE AT AMISTAD DAM THROUGH THE CONSTRUCTION OF A COMPOSITE CUTOFF WALL

To the Honorable Commissioners
International Boundary and Water Commission,
United States and Mexico
El Paso, Texas and Ciudad Juarez, Chihuahua

Madams:

In accordance with your instructions, we respectfully submit for your consideration this Joint Report, proposing the Composite Cutoff Wall Remediation Project as a permanent solution to mitigate the risk of failure from the presence of sinkholes and seepage through the embankment at Amistad Dam (reference Figure 1 of Exhibit I to identify the area of concern). This Joint Report supersedes the "Joint Report of the Principal Engineers Regarding Prompt Remediation Actions Required to Reduce the Risk of Failure at Amistad Dam," dated January 29, 2021.

The "Joint Report of the Principal Engineers Concerning the Division of Operation and Maintenance Costs of Amistad Dam," dated December 1, 1969, which forms an integral part of Commission Minute 235, entitled "Division of Operation and Maintenance Costs of Amistad Dam," signed December 3, 1969, provides in its section *Work of an Extraordinary or Emergency Nature:* "Should it become necessary to perform operation, maintenance, or repair work of an extraordinary or emergency nature which, if not performed promptly might result in risk of serious damage to the project, or in increased cost of its performance, the Commission shall order those works executed which it finds advisable and shall allocate them between the two countries for their performance as soon as possible, understanding that the performance by each Government of the work allotted to it, cannot be undertaken until it has made the necessary financing arrangements therefor."

Furthermore, Minute 210 of the Commission, entitled "Recommendations Regarding Construction of Amistad Dam," dated January 12, 1961, establishes the distribution of construction costs based on the distribution of the conservation capacity of the reservoir, allocating 56.2% to the United States and 43.8% to Mexico. In that sense, in accordance with Article 5 of the Treaty Between the United States of America and Mexico for the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Water Treaty), the construction, operation and maintenance costs of the dam must be divided between the two countries in that proportion.

AMISTAD DAM BACKGROUND

The Amistad International Dam is located on the Rio Grande 11.81 miles (19 kilometers) north of the cities of Del Rio, Texas and Ciudad Acuña, Coahuila. It is the second international storage dam built jointly by the United States and Mexico, pursuant to the 1944 Water Treaty. Construction began in 1963 and was completed in 1969. The total length of the dam embankment is approximately 32,022 feet (9,760 meters). The concrete gravity section in the river channel is 2,182 feet (665 meters), flanked by approximately 8,501 feet (2,591 meters) of earthen embankment in the U.S. and approximately 21,339 feet (6,504 meters) of earthen embankment in Mexico. The concrete gravity section consists of a 951 feet (290 meters) wide spillway equally divided on each side of the international boundary. The concrete dam has a non-overflow transition section 92 feet (28 meters) long on either side of the spillway followed by a 223 feet (68 meters) long intake section. The remainder of the concrete dam consists of a 299 feet (91 meters) long non-overflow section.

The benefits of Amistad International Dam include flood risk management, hydropower generation, water supply, flood control, water quality, fish and wildlife enhancement, and recreation. The U.S. Army Corps of Engineers (USACE) "Amistad Dam, Dam Safety Action Decision Summary" report, from January 2020, mentions that the Amistad Dam and Lake provide a minimum of $76 million dollars annually of public benefits in the U.S., including $8 million for flood risk management, $9 million for hydropower, $7 million for water supply (industrial and municipal), $8 million for irrigation, and $44 million for recreation, fish, and wildlife (costs in 2016 dollars). According to a 2011 study by Texas A&M AgriLife Extension Service, "Economic Impact Estimate of Irrigation Water Shortages on the Lower Rio Grande

Valley Agriculture," by Luis A. Ribera and Dean McCorkle, the annual value generated by irrigation-fed agriculture in the Lower Rio Grande Valley (U.S. side alone) is estimated to be $820 million dollars. In Mexico, this value is estimated at approximately $232 million dollars (agricultural statistics from the Irrigation Districts, 2015-2016 agricultural cycle, CONAGUA).

Population at risk (PAR) during a high pool (elev. 1,145 feet/349 meters) failure event is estimated to consist of 286,278 people during the day and 395,587 during the night. Primary population centers downstream of the dam that are at risk in the event of a failure are Del Rio, Eagle Pass, and Laredo, Texas in the United States, and Ciudad Acuña and Piedras Negras, Coahuila and Nuevo Laredo, Tamaulipas in Mexico. It is estimated that between 1968 and 2014, Amistad International Dam has prevented approximately $129 million dollars in flood-related damages (2014 price level). Average annual flood damages that have been prevented are over $2.8 million dollars. The combined total population (U.S. and Mexico) downstream of Amistad and Falcon International Dams exceeds 2.6 million people.

BACKGROUND ON THE STRUCTURAL SAFETY ASSESSMENT OF AMISTAD INTERNATIONAL DAM

Extensive subsurface flow (springs) has been reported downstream of Amistad Dam since initial reservoir impoundment in 1968. In general, most of this seepage is traveling through the foundation of karstic limestone in the Georgetown formation beneath the subgrade of the embankment section. Most of the springs at Amistad International Dam occur at considerable distances downstream of the dam (328+ feet/100+ m). However, it is worth noting that there is one area on the Mexico side downstream of the earthen embankment where groundwater surfaces as springs at the toe of the dam. This area is identified as V4 and is located between dam Stations km 6+350 and 6+460 (reference Figure 2 of Exhibit I for the location of V4 spring).

At the end of 1994 and in early 1995, as a result of the decline in the Amistad Dam reservoir level, and due to drought conditions, the first sinkholes began to appear in the reservoir near the earthen embankment on the Mexican side at Station km 7+100, which represented a potential risk to the structure's stability (reference Figure 2 of Exhibit I for the location of sinkholes and springs). As a result of this event, daily inspections were initiated of the sinkhole area and the springs area located downstream of the earthen embankment. A series of studies were carried out that included evaluating historical data from the original treatment to the caverns and cracks discovered in the foundation during construction of the dam and grout curtain. In January 1995, the binational group of Technical Advisors to the International Boundary and Water Commission (IBWC) reviewed and analyzed the information compiled in the studies and activities performed, recommending immediately filling the sinkholes, and undertaking works to reinforce the impervious grout curtain as soon as possible.

Consequently, on April 28, 1995, IBWC signed Minute 292, entitled, "Works of an Emergency Nature that should be Undertaken Promptly for Treatment of Sinkholes that have Developed in the Reservoir at Amistad Dam."

Between 1995 and 1996, reinjection treatment was performed on a 182.88 ft (600 m) section of the impermeable curtain between Stations km 6+850 and 7+450, to protect the impermeable core in its contact with karst limestone, reduce existing seepage, and intercept part of the water flow through possible seepage pathways under the dam subgrade coming from sinkholes such as those detected inside the dam's reservoir. This area was identified as having the highest density of fault lines and limestone fracturing. Additionally, piezometric stations and weirs were built to measure the seepage and the impact of the repairs made. By 2001, 25 sinkholes had been detected in front of this area. To date, 55 sinkholes have been identified, of which the last 16 were identified in 2024 during declining reservoir levels.

During the five-year Safety of Dams inspection of Amistad Dam in April 2007, the IBWC Technical Advisors concluded that a large portion of the foundation of the dam is potentially unsafe and that it required further evaluation and study. They recommended that a group of experts be convened for this purpose to guide studies, investigations, analyses, and evaluation of the dam. As part of this five-year inspection, Amistad Dam was categorized as Class II – High Urgency (Potentially Unsafe) under the Dam Safety Action Classification (DSAC) System used by the USACE to evaluate dams. This classification is a consequence of the potential risk of loss of life and economic damage downstream of the dam, requiring urgent safety actions. As of the date of signing of this report, the Commission's Technical Advisors maintain the assigned classification of DSAC-II.

In 2008, a Joint Expert Panel with representatives from the U.S. and Mexico was formed to begin the studies and investigations of the dam. The Joint Expert Panel generated a Consensus Report in 2009 that summarized the results of the initial evaluation, the potential failure mode analysis, and baseline risk assessment, and also offered a number of future studies and action recommendations. In April 2011 the group completed the Quantitative Risk Analysis of Amistad Dam, where they concluded that risks exist that are primarily linked to the potential failure of the dam's earthen embankment and riprap due to the presence of cavities and, to a lesser extent, to a process of increasing seepage through the cavities located under the dam foundation. Seven Potential Failure Modes (PFM) for the dam were defined and assessed as the most likely to pose a risk of failure to the embankment. The first three failure modes were determined to be risk-driving failure modes because they were above the tolerable guidelines established by the USACE (PFM1-Stoping of a pre-existing sinkhole connected to a seepage path; PFM2-Scour at foundation contact; and PFM3-Filter incompatibility). PFM3 was ultimately determined not to be a risk-driving factor after further evaluation.

In 2014, the Joint Expert Panel updated the Quantitative Risk Assessment and re-evaluated PFM1 and PFM2 based on additional information provided about the original construction of the dam embankment.

As part of the Dam Safety Modification Study (DSMS) that was started in 2011, the U.S. and Mexico agreed to conduct geotechnical investigations in 2015 for the purpose of better defining the limits of the foundation problems along the axis of the dam and enabling the risk associated with these failure modes to be better evaluated. The final results from the December 2017 Geotechnical Data Report, "Joint Exploration/Investigations for Support of the Dam Safety Modification Study for Amistad Dam Embankments," prepared by the U.S. company URS, show that in general, the historical information for the dam on the Mexican side reviewed by the Joint Expert Panel is consistent with the exploration data. "Del Rio Clay" type soil material was only found in one boring, which indicates that it was removed from the clay core foundation during the construction of the dam. Likewise, it was observed that the layer of marl was removed from the core foundation between Stations km 6+460 and 6+600. The results of the dye tracer study showed the lack of a clear preferential path between the injection points and the springs areas, which suggests that there is an interconnected network of fractures, faults, seepage pathways, and associated cavities. Most of the seepage during the time of the investigation was suspected to have originated between Stations km 6+700 and 8+300 and to be influenced by two (2) major geological faults, which traverse the area in an east-west and north-south direction, respectively. Also, large cavities were found in the area of influence for the V4 spring below the base of the downstream slope of the dam. Three (3) geologic faults cross the dam at the V4 spring location, which may be enabling groundwater to flow north-south.

Using the information from the 2015 URS geotechnical investigations, the Joint Expert Panel re-evaluated three Potential Failure Modes and updated the Quantitative Risk Assessment in 2017 as part of the DSMS Study. This study focused on addressing the potential risks associated with material loss in the karstic seepage pathways developed in the marl and limestone below the dam's subgrade level, which could eventually lead to a dam breach and failure. PFM1-Stoping of a pre-existing sinkhole connected to a seepage path and PFM2-Scour at foundation contact were confirmed to be the two risk-driving failure modes for Amistad Dam that could seriously affect the dam's structural integrity from Station km 6+000 to 8+000 of the embankment on the Mexican side. The estimated risk of a failure resulting from PFM1 and PFM2 exceeded both the USACE and U.S. Bureau of Reclamation guidelines for tolerable risk.

The Joint Expert Panel recommended that corrective actions be investigated to reduce the risk to within tolerable risk guidelines. Furthermore, after reviewing the risks identified in the studies developed by the Joint Expert Panel, the Commission's Technical Advisors maintained the assigned designation of DSAC II – High Urgency (Potentially Unsafe) during the five-year structural safety inspection of the dam in 2017.

Based on the review of the studies prepared by the USACE in collaboration with Mexico's National Water Commission and the United States Bureau of Reclamation, and their recommendations, different factors, such as structural safety, loss of human life, material damages, design, estimated construction costs, construction time, equipment, availability of materials, and availability of resources, were analyzed for each alternative. Based on the evaluation of these factors, the *Downstream Overbuild with Filter* was recommended to be selected as the interim remediation alternative in the "Joint Report of the Principal Engineers

Regarding Prompt Remediation Actions Required to Reduce the Risk of Failure at Amistad Dam," dated January 29, 2021, given each Government's funding constraints considered at that time.

EVALUATION OF THE REMEDIATION ALTERNATIVES IDENTIFIED IN THE DSMS STUDY

The studies and reports carried out by the Joint Expert Panel have clearly explained the geological-geotechnical conditions of the foundation rock associated with the Amistad Dam risk factors. The presence of a system of existing faults and fractures in the foundation rock (made up of marls and limestone from the Georgetown formation) on the embankment on the Mexican side of the dam have led to the concentration of water flows, creating cavities and dissolution channels, which have been increasing in size over time, generating preferential flow paths involving seepage flows that can vary between 24.7 cubic feet per second (cfs) to 105.9 cfs (0.7 to 3 cubic meters per second [cms]).

Based on the results of the Quantitative Risk Assessment and to address incremental risk, a wide variety of measures and Risk Management Plans (RMPs) were considered. Some of the measures considered were: removal of the dam, which was judged to waste too many benefits and to be inefficient; Future Without Action Condition (FWAC) was considered and compared to each of the RMPs but failed to meet tolerable societal risk; and the non-structural measure of a permanent pool restriction at the low elevation of 330m above sea level (asl) did not reduce the risk and was deemed unacceptable due to the loss of project benefits. When compared to each other, RMP 1 (Composite Cutoff Wall) was the only one that met the societal tolerable risk guidelines, while RMP 2 (downstream overbuild) and RMP 3 (upstream overbuild) plotted within the intolerable range, plus failed to address the problem of flowing water under the dam.

Of the three alternatives evaluated, only the Composite Cutoff Wall meets all of the tolerable risk guidelines established by the USACE for a permanent solution (see Figure 3 of Exhibit I). The downstream or upstream overbuild options, while they do not meet all USACE guidelines to be considered permanent solutions, are very close to meeting the tolerable risk guidelines and are therefore considered interim solutions.

The option of permanently reducing the conservation level of the reservoir was assessed as a non-structural measure. The preliminary study conducted by the USACE found that it is possible to reduce the risk by permanently lowering the conservation level; however, the remaining risk was above the tolerable risk guidelines. With this measure, all of the dam's benefits, such as water supply for domestic and agricultural uses, water quality, hydropower generation, flood control, fish and wildlife enhancement, and recreation would be directly affected. Thus, it was determined that this alternative was not viable for implementation by the Commission.

SELECTION OF THE PERMANENT REMEDIATION ALTERNATIVE: COMPOSITE CUTOFF WALL

In subsequent meetings between both Sections of the Commission, in coordination with their Technical Advisors, the various risk factors, including loss of human life and material damages, were analyzed. Based on these criteria, this led to the selection of the permanent remediation alternative since it is the only solution that meets all tolerable risk guidelines established by the USACE (see Figure 3 of Exhibit I). While the Composite Cutoff Wall alternative has the highest cost, it also represents the greatest risk reduction.

At the Principal Engineers meeting on June 29, 2022, the proposed permanent solution of the Composite Cutoff Wall alternative was reviewed and analyzed. In the subsequent meeting of the Commission and its Technical Advisors on October 5-6, 2022, it was recommended to select the permanent solution of the Composite Cutoff Wall for implementation in a 2.0 km section of the embankment on the Mexican side, between Stations km 6+000 to 8+000; this area is where the largest amount of seepage, faults, and geological discontinuities are concentrated and where there have been the greatest number of sinkholes or collapses close to the dam's earthen embankment.

On January 30, 2024, during the five-year dam safety inspection site visit, the IBWC Technical Advisors found 10 new sinkholes on the Mexican side of the dam. The 10 new sinkholes of varying dimensions were observed near the toe of the upstream dam embankment, located between Stations km 5+770 and 6+256. These sinkholes were exposed by the lowering of the water in the reservoir due to Mexican water releases that were in process at the time.

Due to the potential high risk to the stability of the dam because of the new sinkholes, on February 21, 2024, the IBWC's Technical Advisors (geology-geotechnical experts) inspected the new sinkholes to determine a remediation for them. By the end of the water releases on March 2, 2024, a total of 16 new sinkholes had been discovered.

Upon review of the five-year safety inspection report recommendations and the new sinkholes found in 2024 by the IBWC Technical Advisors (geology-geotechnical experts), it was determined to extend the length of the Composite Cutoff Wall project by 607.0 meters starting from Station km 6+000 eastward, in order to account for the area of the new sinkholes at the upstream toe of the slope, making the new total length of the project 2.6 km, starting at km 5+393 (where the earth embankment begins) and ending at km 8+000, as described in the "Technical Report for the Length Extension of the Amistad International Dam Composite Cutoff Wall Project," dated October 8, 2024 (included as Exhibit II and forms a part of this Joint Report).

The Composite Cutoff Wall consists of the following two structural measures (see Figures 4 and 5 of Exhibit I):

1) A two-line grout curtain (first upstream and second downstream)

2) A concrete cutoff wall

Each grout curtain consists of a line of boreholes parallel to the dam, drilled from the crest and backfilled with pressurized cement grout mix. The purpose of the grout curtains is to fill fissures, fractures, seepage pathways, and cavities in the karstic bedrock; to obtain additional information to define in greater detail the concrete cutoff wall depth and extent; and to permit the construction of the cutoff wall by blocking water flow and thus preventing the risk of collapse of the wall during excavation.

The intent of the concrete cutoff wall is to guarantee the structural and functional safety of Amistad Dam, controlling the seepage from the reservoir. The concrete cutoff wall is proposed to be constructed by excavating a series of panels from the crest of the embankment between the two grout lines. Cutoff wall panel excavations would terminate at a depth below the rock strata that currently convey flow or could possibly do so in the future. Metal pipes would then be inserted and used to pump concrete from the bottom to the top of the excavation. The concrete cutoff wall panels would be constructed in a primary-secondary sequence, with required overlap, thickness, and verticality thresholds at the primary-to-secondary element joints. The above methods are based on the information available as of the date of this Joint

Report and may be subject to review and validation by the Commission's Technical Advisors during the project design phase.

The Composite Cutoff Wall alternative does not require the acquisition of real estate in order to construct, operate and maintain the project, and the project is not anticipated to involve permanent utility/facility relocation within the work limits. The environmental impacts are also expected to be minimal.

The Composite Cutoff Wall alternative is a standard technique for reducing risk of failure in dams with karst foundations. This measure is constructible with proven technology and minimum risk to the project, with advantages such as:

- Limited earthwork required.
- Conventional construction techniques/methods.
- Modern techniques allow close monitoring of the foundation.
- Low environmental impact.
- Disturbance of the embankment core can be minimized.
- No additional Operations and Maintenance (O&M) costs.
- A very small portion of the foundation is exposed at any one time, as construction occurs in panels.
- No pool restrictions are required.
- Mitigates the risk based on the DSAC guidelines (from DSAC II to DSAC III).
- Lower probability of unsatisfactory performance at pool levels above the conservation level.
- Decreased water pressure in the foundation of the dam.
- Reduces potential for sinkhole development upstream of the cutoff wall.
- Reduces potential for foundation and embankment erosion within the depths of the wall.
- Impedes initiation of erosion piping.
- Repair expected to last service life of the dam.

It is anticipated that the Composite Cutoff Wall alternative will include four main work stages:

1) Construction of a temporary road to bypass public traffic away from the crest of the dam (this will be at the Commission's discretion, as the crest of the embankment may be completely closed, and other alternatives may be explored to reroute traffic). This action will be coordinated with the corresponding port officials as needed.
2) Construction of a temporary work platform to widen the crest of the dam to accommodate the heavy machinery and equipment that will be used to perform the remediation work.
3) Construction of a two-line grout curtain which is composed of a series of boreholes drilled along two parallel alignments (upstream and downstream limits will be defined during the grout curtain design) where the boreholes intersect geologic faults in the bedrock, which are filled with cement grout mixes and other aggregates. Exploratory holes will be drilled in advance to more precisely define the design and construction of the grout curtains.
4) Construction of a cutoff wall that will be excavated vertically through the crest of the dam and into the bedrock to a chosen depth in panels, which are then backfilled with concrete to provide a flow barrier for water running through the flow paths in the bedrock (reference Figure 5 of Exhibit I: Composite Cutoff Wall Project Concept).

As the Composite Cutoff Wall meets all of the tolerable risk guidelines described in the DSMS, it is proposed that the project be initiated utilizing funds available from each Section of the Commission and that both Sections request the additional funding necessary to implement this permanent solution, ensuring the completion of the Composite Cutoff Wall project.

DESIGN AND CONSTRUCTION PROPOSAL

We propose that design and construction of this project be carried out in the manner described in this section.

During the construction process for the grout curtains, exploratory boreholes will be drilled to confirm or adjust the required design dimensions of the grout curtains and the cutoff wall. New geological data will be incorporated to update the existing 3D model of the work area.

The construction will begin with the upstream grout curtain. The construction of the grout curtain includes recommended exploratory borings every 30 meters (15 degrees from vertical), followed by primary intermediary holes spaced every 10 meters and 2nd and 3rd order holes, etc., as needed. Then the construction will continue with the downstream grout curtain, 15 degrees from vertical in the opposite direction of the upstream grout curtain. The grout curtains must extend to a designed minimum depth below the predetermined limits of the cutoff wall.

The depth of the grout curtains is one of the biggest considerations, and they must be deep enough to intercept all karst features to then determine the starting and ending limits and depth of the cutoff wall.

Once the final dimensions of the cutoff wall are determined (depth and limits of the project area), it will be constructed in the confined area between the two grout curtains that were constructed previously. The construction of the cutoff wall will be done by excavating alternate panels (primary and secondary) to the depth defined in the project, then concrete will be placed on said panels.

The above methods are based on the information available as of the date of this Joint Report and may be subject to review and validation by the Commission's Technical Advisors during the project design phase.

Table 1 – PROPOSED DESIGN AND CONSTRUCTION SCHEDULE

ITEM	**SCHEDULE**
Solicitation	4 months
Design	6 months
Construction of the Composite Cutoff Wall	30 months

ESTIMATED COST OF THE COMPOSITE CUTOFF WALL PROJECT

The Commission should analyze the estimated cost information from 2018 of the recommended alternatives in the DSMS, as well as the inflation factors and additional expenses associated with the length extension of the Composite Cutoff Wall project, with the aim of determining the final cost of this project. This will allow the Commission to update the data to reflect current costs at the time the project is to be implemented.

The distribution of the total cost of the project will be carried out in accordance with Minutes 210 and 235 of this Commission, which establish 56.2% for the United States and 43.8% for Mexico.

MAINTENANCE

No additional Operations and Maintenance (O&M) costs are anticipated for the proposed Composite Cutoff Wall solution. Current operations and maintenance are anticipated to remain the same during implementation of the solution. If, during the development and implementation of the Composite Cutoff Wall work, additional maintenance is required, the costs generated by this item will be distributed between both countries in accordance with Minutes 210 and 235 of this Commission.

If new sinkholes form in the dam reservoir during the development and implementation of the Composite Cutoff Wall work, existing repair protocols and treatment will be applied to mitigate the sinkhole progression, as recommended by the Mexican Technical Advisors in the Report of the Inspection Visit to the Amistad International Dam, Texas-Coahuila, dated June 7, 2000. This treatment involves the repair or placement of any missing granular material for the pre-existing sinkholes and/or placement of granular material in new sinkholes per the established repair and treatment protocols. The costs generated by this item, as well as any inherent work required for this cutoff wall construction project and its subsequent operation, should be distributed between both countries in accordance with Minutes 210 and 235 of this Commission.

If any failure in an embankment section or loss of granular filter material or rock were to occur during the development and implementation of the Composite Cutoff Wall work, the

Commission should immediately contact its Technical Advisors to initiate an assessment of the possible causes of these anomalies and to recommend urgent remediation measures to prevent the failure of the dam.

MINIMUM REQUIREMENTS THAT MUST BE MET BY THE CONTRACTOR FOR THE DESIGN AND CONSTRUCTION OF THE COMPOSITE CUTOFF WALL

The selected design contractor's proposed permanent solution should include, among other concepts, the geological-geotechnical analysis of the new and existing information to determine the required number of boreholes, inclination, and depth required for the upstream and downstream grout curtains, the construction of both grout curtains, the determination of the starting and ending limits and depths of the cutoff wall, and any ancillary required works.

In addition, the design contractor should have experience in the design of cutoff walls for dam safety and/or similar projects that must include, among other concepts, the work needed for the cutoff wall construction; preliminary activities; excavation to prescribed depths; disposal of materials; and concrete construction to required depths, dimensions, and quantities; and any required ancillary works.

The contractor selected to construct the proposed permanent solution should meet the following requirements:

a) Have experience in design and construction of projects of similar scope and magnitude.

b) Have specialized departments with experience in geological, geotechnical, civil, structural, and environmental engineering and cost estimating, that have participated in the design and construction of projects of similar scope and magnitude.

CONCLUSIONS

The proposed Composite Cutoff Wall meets every tolerable risk guideline. It is the only alternative that reduces the societal risk to a tolerable level. It also meets the following important considerations:

- There is a plan in place to communicate flood risk to the affected communities, stakeholders, and emergency management personnel.

- The Commission has a robust monitoring and inspection program (including periodic Safety of Dams inspections), an updated Emergency Action Plan, and clear risk characterization from the USACE DSMS.
- The Commission will periodically assess risks in the future to ensure that they are properly monitored and managed.

RECOMMENDATIONS

We therefore recommend the following:

1. The two Sections of the Commission shall implement the Composite Cutoff Wall alternative, including complementary and ancillary works, in a proposed 2.6-kilometer reach from Stations km 5+393 to 8+000 (Figure 4 of Exhibit I) on the Mexican side of the Amistad Dam embankment, in accordance with the "Technical Report for the Length Extension of the Amistad International Dam Composite Cutoff Wall Project," dated October 8, 2024, included as Exhibit II, which forms an integral part of this Joint Report. The results of the project design and exploratory borings in the construction phase shall determine the final dimensions of the Composite Cutoff Wall.
2. Given that the Composite Cutoff Wall and its complementary and ancillary works will be undertaken in Mexico, the Mexican Section shall manage the solicitation and contracting for the design, construction, construction management, and/or project management in consultation with the U.S. Section.
3. All work shall be under the joint supervision of both Sections of the Commission and their Technical Advisors.
4. Both Sections shall request the funding necessary to ensure that the Composite Cutoff Wall is fully constructed and that the distribution of the total cost of the project is carried out in accordance with Resolution 2(b) of Commission Minute 210 and Resolution 3 of Commission Minute 235 that establish 56.2% for the United States and 43.8% for Mexico.

5. The two Sections in Del Rio, Texas and Cd. Acuña, Coahuila shall continue their routine data exchange and monitoring programs of the dam's automated and conventional instrumentation, as well as the measurement of spring flows in the Mexican portion of the dam, to detect any abnormalities that are happening in the dam structure and identify emergency actions for their repair or treatment.
6. If new sinkholes form in the dam reservoir during the development and implementation of the Composite Cutoff Wall construction, the existing repair protocols and treatment recommended by the Commission's Technical Advisors shall be applied.
7. Both Sections shall annually review and update the list of the officials identified in the Amistad Dam Emergency Action Plan.
8. If additional work is required as a result of construction of the Composite Cutoff Wall, the costs of such work shall be distributed between the two Sections in accordance with Resolution 2(b) of Minute 210 and Resolution 3 of Minute 235 of this Commission, subject to the availability of funds.
9. To minimize risks associated with water storage levels above the conservation pool, both Sections shall commence work at the earliest time possible, taking advantage of the current low levels in the reservoir. Should the reservoir levels rise during the construction process, both Sections shall take necessary measures to ensure the work is performed in its entirety and done in a safe manner, subject to the availability of funds.

Respectfully submitted,

Ramon Macias III
Principal Engineer
United States Section

Agustin Boone Gonzalez
Principal Engineer
Mexican Section

EXHIBIT I

Figure 1: Amistad Dam Area of Concern

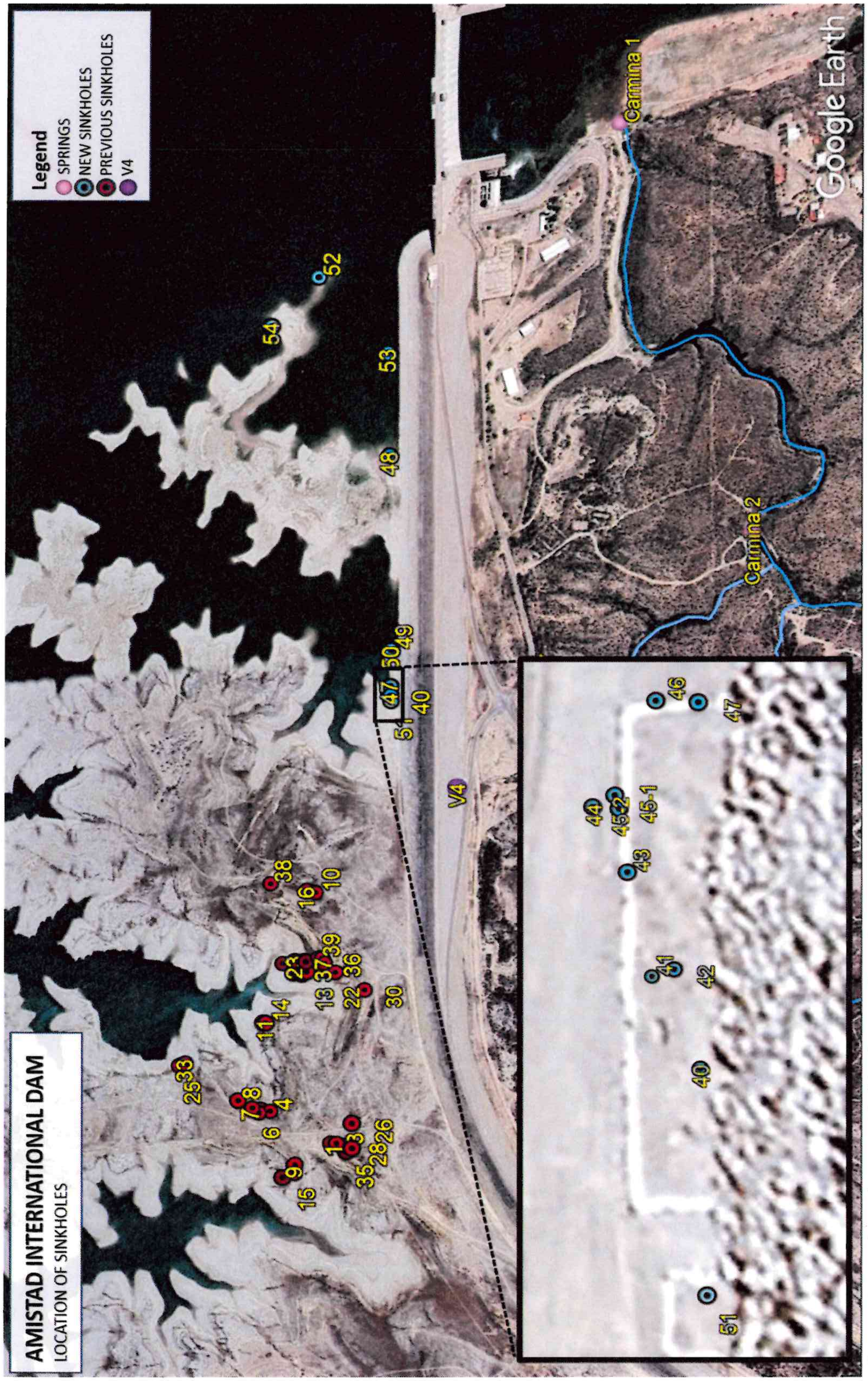

Figure 2: Amistad Dam Sinkholes and Springs

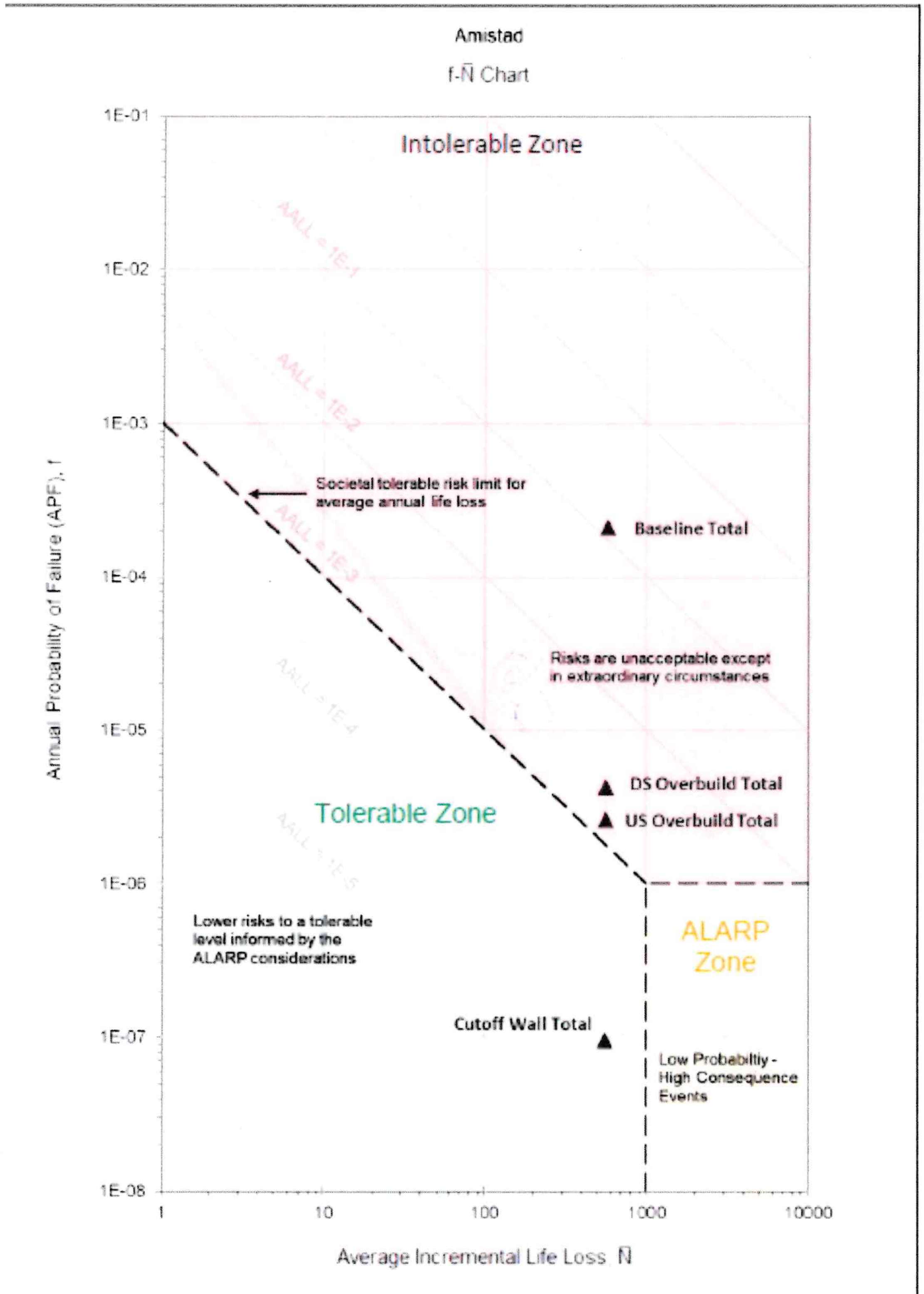

Figure 3: f-N Chart of Alternatives for Comparison of the tolerable risk guidelines established by the USACE

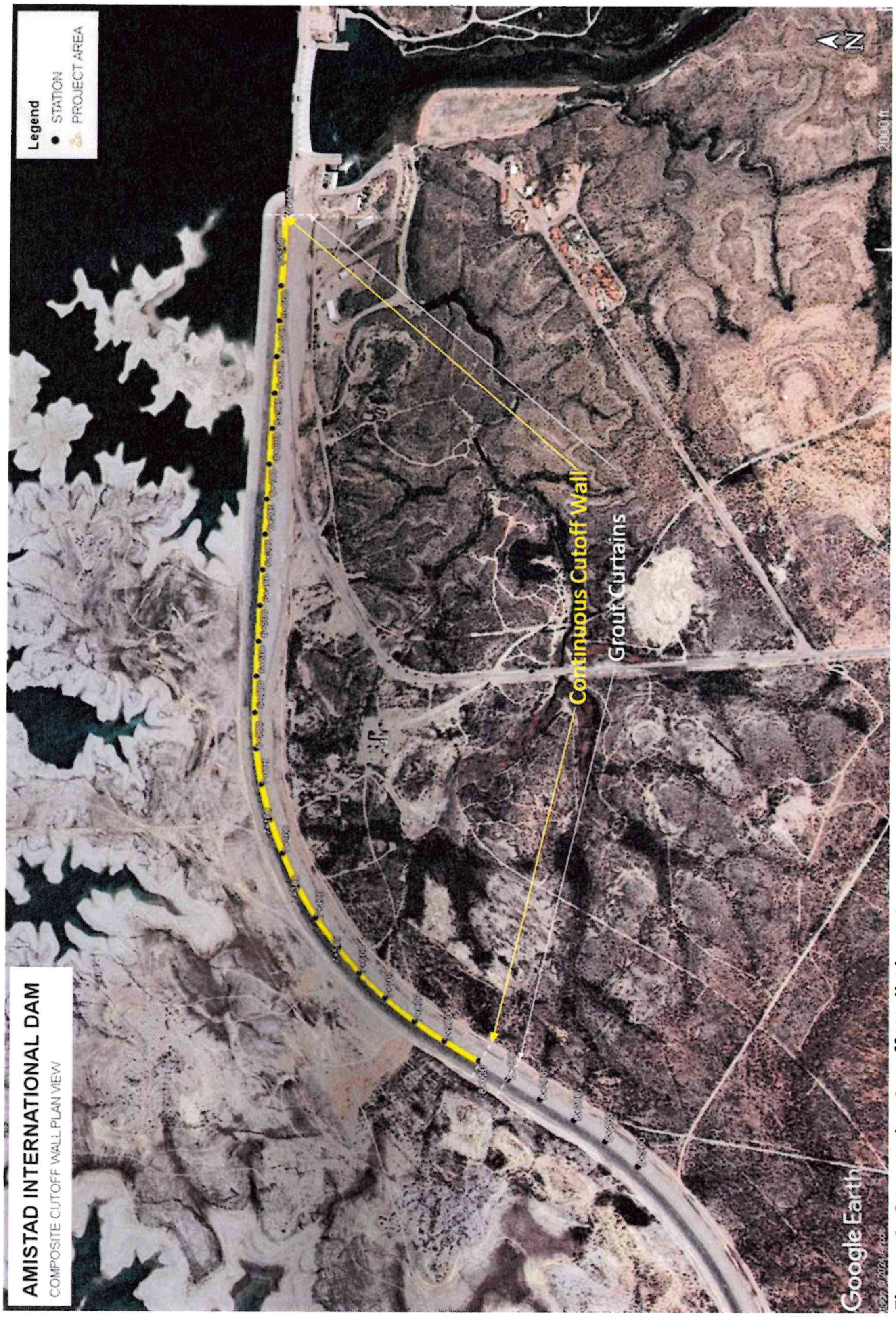

Figure 4: Composite Cutoff Wall Plan View

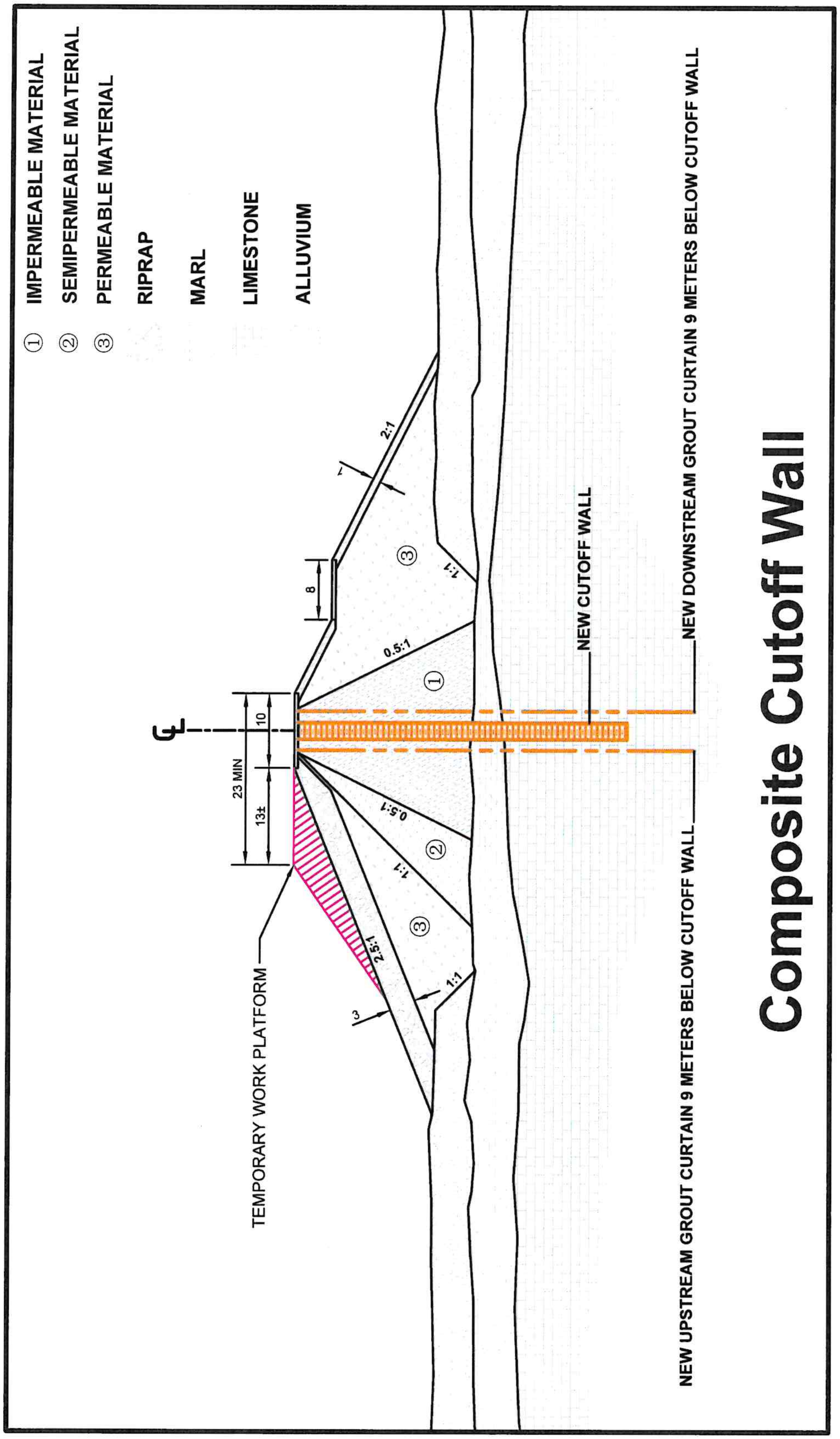

Figure 5: Composite Cutoff Wall Project Concept

EXHIBIT II

INTERNATIONAL BOUNDARY AND WATER COMMISSION
UNITED STATES AND MEXICO

October 8, 2024

EXHIBIT II OF THE JOINT REPORT OF THE PRINCIPAL ENGINEERS ON THE IMPLEMENTATION OF CORRECTIVE MEASURES TO REDUCE THE RISK OF FAILURE AT AMISTAD DAM THROUGH THE CONSTRUCTION OF A COMPOSITE CUTOFF WALL

TECHNICAL REPORT FOR THE LENGTH EXTENSION OF THE AMISTAD INTERNATIONAL DAM COMPOSITE CUTOFF WALL PROJECT

In compliance with the five-year joint inspections program that the International Boundary and Water Commission (IBWC) has established for the safety of international dams, a site visit was conducted at Amistad International Dam on January 30 and 31, 2024. Both Sections of IBWC and their Technical Advisors from the U.S. Army Corps of Engineers (USACE) and Mexico's National Water Commission (CONAGUA) participated.

During the site visit, new sinkholes were found in the dam reservoir due to low storage conditions. For this reason, since the five-year inspection, both Sections' personnel have made frequent site visits to the dam's reservoir and taken readings of the installed instrumentation. More sinkholes were identified and recorded in the site visit logs during the month of February 2024.

To date, 16 new sinkholes have been found, in addition to the 39 that had previously been recorded through 2023. Between Stations kilometer (km) 5+450 and 6+265, there are 14 sinkholes near the toe of the embankment slope and two more in the area of the dam reservoir at 221 m and 320 m from the toe of the upstream slope of the embankment.

Due to the high risk to the structural stability of the dam's embankment posed by the new sinkholes, on February 21, 2024, the Commission, with its Technical Advisors who have geotechnical expertise, carried out an inspection in the area where the new sinkholes are located, to determine the appropriate remediation actions for the new sinkholes.

BACKGROUND

The dam's subgrade is overlying limestones, fault zones and major fractures that pass through the Georgetown formation. The principal paths of groundwater flow are through interconnecting dissolution faults. Dissolution of limestone occurs along them, causing the development of sinkholes or expanded caverns and elongated narrow faults. The intersections of faults combined with fracturing systems are particularly intense dissolution zones, frequently causing caverns and sinkholes to form.

The seepage water comes from the reservoir and flows below the dam embankment through a system of faults and fractures that are expanded by the water dissolution through the various limestone strata. This water emerges downstream of the dam as springs in the pervious zones. Differential dissolution also occurs due to contrasts in the type of limestone. Clay limestones and marls are less susceptible than pure limestones. Consequently, the joints and faults that are expanded by the water dissolution, and the cavern walls show differences in water dissolution depths due to these lithostratigraphic controls. The presence of intercalated shale also affects the groundwater flow paths since it is of low permeability, which contributes to the dissolution by groundwater.

The dissolution processes described above, as well as the associated permeability within the Cretaceous Georgetown Limestone formation, have formed karstic features over geological periods that represent the predominant rock under the earthen embankment and reservoir.

During the dam's design period in the early 1960s, it was noted that the limestone contained numerous dissolution characteristics. Depressions, sinkholes and caverns were observed to some extent on the valley walls, river terraces and adjacent plains.

Based on the original topography, the exposed geology, and the presence of closed depressions, old sinkholes, cavities or caverns in the limestone cliffs, and pre-existing springs, it was determined that the limestone area is of the karstic type, and it was determined that a deep grout curtain was required. Dissolution openings and sudden water losses in the boreholes had been detected during the exploratory drilling studies.

Construction of the grout curtain consisted of one line, 50 m deep, with mandatory 1st stage and 2nd stage borings spaced at 6.10 m and 3.05 m, respectively. In third and fourth stage borings, grout consumption was high because cavities or caverns, faults, joints, expanded stratification, and dissolution faults were encountered.

During the construction period from 1964 to 1965, with the cleanup excavation carried out for the foundation in the trench excavated for the dam's impervious core rockfill foundation, dissolution faults, faults, and caverns, some of which were filled with clay material and/or stone material, were discovered; this required detailed clearing, and the caverns and elongated dissolution faults were filled with conventional concrete. These anomalies were also injected with cement grout.

Along the dam embankment from Stations km 5+393 to 8+000, the lithostratigraphy can be characterized as approximately 5 m of clayey gravel, corresponding to the alluvial terrace overlaying the Georgetown formation. The upper first few meters of the Georgetown formation, approximately 6 to 8 m deep, were designated as "marl," but the zone is composed of alternating shales that are thinly layered with interbedded karstic limestone, which had the most karstic dissolution caverns and faults. Karsticity is also found along faults, dissolution faults, joints, overlaying marl bedding planes, and in the purest limestone area of the Georgetown formation.

During construction, it was determined that there was at least moderate karsticity in the area, with the potential for seepage around the embankment, and under and through the grout curtain where there is incomplete or partial filling of the dissolution openings that are partially filled with clays or stone material. Over time and due to seepage, the effectiveness of the grout curtain could decrease due to erosion from contact with the embankment's clay core foundation.

Since 1968, the year in which the dam was impounded, several springs emerged downstream of the embankment, and seepage began, continuing to date. The most complete record is from the Carmina Spring. The flow was about 400 liters per second (lps) in early 1969, when the reservoir capacity had reached an elevation of 322 m above sea level (asl). Flow increased to 900 lps in early 1971, with the reservoir level at an elevation of 328 m asl. It then increased evenly over the next 2 years to a maximum of 2,000 lps, with the reservoir level reaching an elevation of 343 m asl. The reservoir level reached its highest elevation for a short period on September 22, 1974, at an elevation of 346.15 m asl, and the Carmina Spring also reached a peak flow of 2,140 lps.

The reservoir levels have decreased to an elevation of 334 m asl between 1983 and 1984; 329 m asl in 1986; 332 m asl in 1990; and 332 – 331 m asl in 1994 and towards the end of 1995. The flows of the Carmina Spring decreased to 1500, 800, 1550 and 1100 lps, respectively. Reservoir measurements and spring gauging indicate a nearly linear relationship between reservoir elevation and spring outflow. However, from 1982 to 1986 and 1990 to 1993, the Carmina Spring flow increased by 20% with respect to the higher water surface elevations of the reservoir.

This increase may have been due to eroding clay as a result of the flowing water in the partially clay-filled karst faults or by the formation of new sinkholes at the bottom of the reservoir, especially during low water elevation periods in the reservoir. Either of the two causes mentioned above allows an increased inflow of water into the karst limestone from the reservoir.

Monitoring of springs V-4, MG-13, MF-13, La Burbuja, Hilda, Lourdes, and Carmina 2 indicate discharges of less than 100 lps, some of which show artesian pressure. Currently, the accumulated outflow to the Jaboncillos collector, located 7 km downstream of the dam, is approximately 2,170 lps. The Carmina Spring slowly increased, with a total output of about 3,400 lps. There is a good correlation between reservoir levels and seepage.

Piezometer levels in the area downstream of the dam increased from 20 m to 35 m, and up to 10 m at a distance of 5 km downstream. There are no records of new sinkholes forming during the first three low reservoir periods.

During the months of September to November 1994, several sinkholes were discovered in the shallow water near the embankment at Station km 7+000; one had water circulation and seepage. Several additional small sinkholes were discovered in January 1995; it is likely that these sinkhole collapses occurred during that low reservoir period.

A hydrogeochemical study was carried out in September and October 1994, which compared the reservoir water with the water from a series of springs downstream of the dam. The results indicated that the spring water is essentially identical to the reservoir water. Although coliform counts were similar, some springs farther downstream showed a mixture of waters with a higher bicarbonate content.

When sinkhole No. 1 was formed, an isolation procedure was implemented by building a cofferdam around it. With the reduced flow of water into the sinkhole, the water level within the sinkhole dropped about 3 m and stabilized at an elevation of approximately 328.5 m asl. Concurrent with the reduction in water inflow, downstream spring MF-13 had a reduction in discharge from 43 lps to 19 lps. At that time, the sinkhole walls collapsed, allowing the reservoir water to cover the sinkhole again. The collapsed material formed only a partial obstruction to the flow. Spring MF-13 increased its discharge again, but only to 32 lps and not to the previous discharge of 43 lps.

Two additional events occurred while sinkhole No. 1 was isolated. A second smaller sinkhole formed a few meters away when the first sinkhole had reached its lowest water level. A series of air bubbles then rose to the surface along a straight line in the shallow water as the sinkhole walls collapsed, compressing the air in the dissolution faults.

In September 1994, under low reservoir conditions, a tracer study was conducted and within approximately 21 hours a pathway was identified between sinkhole No. 1, which is located approximately 275 m upstream of the dam axis, and spring MF-13, which is located approximately 400 m downstream of the dam axis. On November 9, 1994, a second study was performed on sinkhole No. 1 and this time the travel time was 9 hours; the shorter time was probably due to more frequent observations. The apparent flow velocity through the foundation rock was about 90 m/hour (2.5 cm per second).

Geophysical investigations were also performed between the new sinkhole and the dam. Several zones with anomalies were noted. During the drilling of bore hole B-4, one of 5 new borings, a cavity was encountered between the depths of 17.37 and 18.80 m associated with a loss of water flow. As a result of this investigation, it was determined that the sinkholes are aligned along a fault with parallel fracture systems that also had dissolution faults intercepting the karst limestone bedding planes.

From 1994 to date, 55 sinkholes have formed between Stations km 5+450 and 7+100, with water losses of up to 1 cubic meter per second (cms). Water seepage passes under the embankment through fractures and faults that connect to karstic zones in the Georgetown Limestone and emerge downstream as seepage or springs.

Analyzing the interpretation of the original injections provides information on the sections with the highest cement slurry consumption, which may correspond to caverns and dissolution faults in the karstic limestone. Water from the reservoir enters the permeable karstic zone through two routes: the caverns within the reservoir and through sinkholes. The sinkholes may be old or new and may be clean or partially or completely filled. The new ones may form during low reservoir periods, particularly where there is an alluvial terrace or marl cover.

Near the embankment, water within the karstic zone may seep downstream, leaving the piezometric level in that zone below the reservoir level. The hydraulic pressure supporting the karstic cavern is reduced, which may result in stoping and cause the marl material and the alluvial terrace to fall, coupled with a downward hydraulic gradient. This process causes a chimney effect that can reach the reservoir bottom, forming a sinkhole.

LENGTH OF THE PROPOSED COMPOSITE CUTOFF WALL

Considering the above and analyzing the recommendations of IBWC's Technical Advisors, it is proposed to extend the length of the Composite Cutoff Wall project and add approximately 607 m (from Station km 6+000 to the east) to the original 2-kilometer length that was recommended at the meeting of the Commission and its Technical Advisors on October 5 and 6, 2022. Therefore, the total length of the project will be approximately 2.6 km starting at Station km 5+393 (beginning of the clay-cored rockfill section) and ending at Station km 8+000.

Beginning the Composite Cutoff Wall project at the new Station km 5+398 will provide for the rehabilitation to include the area of the embankment where the new sinkholes were found. This reinforces the structural and functional safety of the Amistad Dam embankment.

Respectfully submitted,

Ramon Macias III	**Agustin Boone Gonzalez**
Principal Engineer	**Principal Engineer**
United States Section	**Mexican Section**

EXHIBIT II.A. Location of sinkholes

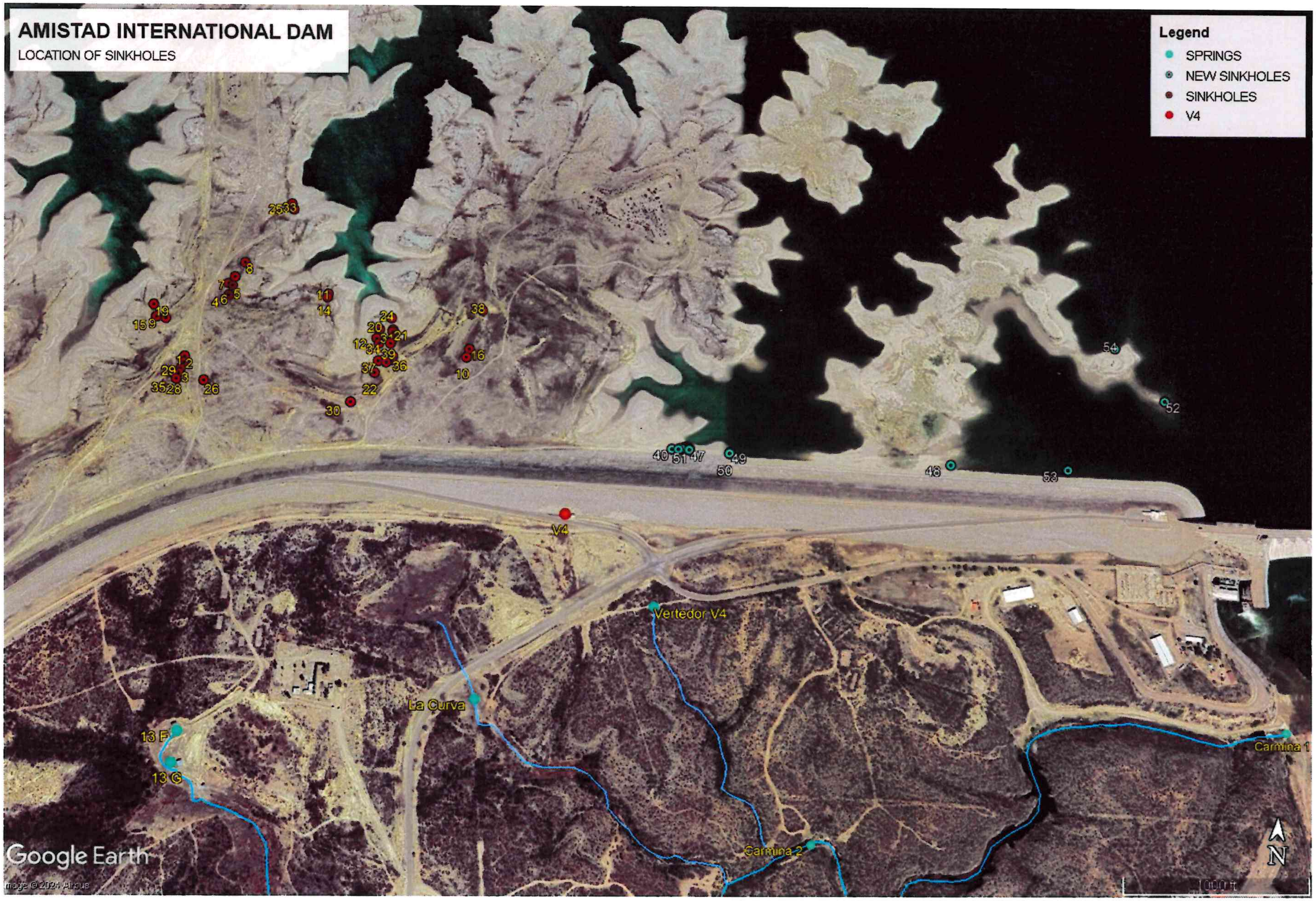

EXHIBIT II.B. List of sinkholes found in 2024

	Identification	Location	Coordinates UTM WGS 84	Depth
1	SINKHOLE 40	TOE OF UPSTREAM SLOPE KM 6+256	299,203.899 E 3,259,699.087 N	0.68 m
2	SINKHOLE 41	TOE OF UPSTREAM SLOPE KM 6+251	299,208.766 E 3,259,701.622 N	0.96 m
3	SINKHOLE 42	TOE OF UPSTREAM SLOPE KM 6+250	299,209.155 E 3,259,700.32 N	1.55 m
4	SINKHOLE 43	TOE OF UPSTREAM SLOPE KM 6+241	299,214.366 E 3,259,702.729 N	1.18 m
5	SINKHOLE 44	TOE OF UPSTREAM SLOPE KM 6+240	299,218.016 E 3,259,704.556 N	0.18 m
6	SINKHOLE 45-1	TOE OF UPSTREAM SLOPE KM 6+238	299,218.599 E 3,259,703.312 N	1.48 m
7	SINKHOLE 45-2	TOE OF UPSTREAM SLOPE KM 6+238	299,217.709 E 3,259,703.086 N	0.1 m
8	SINKHOLE 46	TOE OF UPSTREAM SLOPE KM 6+232	299,223.64 E 3,259,701.013 N	1.55 m
9	SINKHOLE 47	TOE OF UPSTREAM SLOPE KM 6+230	299,223.302 E 3,259,698.783 N	1.01 m
10	SINKHOLE 48	TOE OF UPSTREAM SLOPE KM 5+770	299,689.247 E 3,259,690.271 N	0.14 m
11	SINKHOLE 49	TOE OF UPSTREAM SLOPE KM 6+157	299,297.727 E 3,259,697.277 N	0.15 m
12	SINKHOLE 50	TOE OF UPSTREAM SLOPE KM 6+162	299,295.804 E 3,259,695.576 N	0.15 m
13	SINKHOLE 51	TOE OF UPSTREAM SLOPE KM 6+265	299,192.607 E 3,259,699.859 N	0.15 m
14	SINKHOLE 52	DAM RESERVOIR KM 5+373	300,079.365 E 3,259,826.011 N	0.10 m
15	SINKHOLE 53	TOE OF UPSTREAM SLOPE KM 5+550	299,897.68 E 3,259,689.21 N	0.20 m
16	SINKHOLE 54	DAM RESERVOIR KM 5+450	299, 996.847 E 3,259,925.181 N	0.10 m

EXHIBIT II.C. Photographic report of sinkholes found during January and February 2024






January 30, 2024 — The sinkholes identified with consecutive numbers from #40 to #48 were detected in an area at the toe of the upstream slope between km 5+770 and 6+230.


February 07, 2024 — The sinkholes identified as #49 and #50 are observed at the toe of the upstream slope of the embankment.

February 08, 2024 A new sinkhole was detected and labeled #51 based on the next consecutive number.

February 16, 2024 Sinkhole #52, located at Station km 5+373, 211 m away from the embankment.

February 21, 2024 Sinkhole #53 is identified at the toe of the upstream slope at Station km 5+560.

February 26, 2024	Sinkhole #54 located at Station km 5+450 was observed 320 m away from the toe of the upstream slope.