Gray & Osborne, Inc.
CONSULTING ENGINEERS

TECHNICAL MEMORANDUM 20434-3

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FROM:	KEITH STEWART, P.E. RUSSELL PORTER, P.E. MYRON BASDEN, P.E., S.E. ALEX QUINN, P.E.
DATE:	SEPTEMBER 16, 2021
SUBJECT:	SUDDEN VALLEY WTP TIER 2/TIER 3 SEISMIC EVALUATION LAKE WHATCOM WATER & SEWER DISTRICT, WHATCOM COUNTY, WASHINGTON G&O #20434.00

STRUCTURAL SCOPE OF WORK

In 2019, the Lake Whatcom Water & Sewer District (District) contracted with Gray & Osborne to perform a condition assessment for their existing Sudden Valley Water Treatment Plant (WTP) as part of a larger effort to analyze the District's water treatment facilities in order to prioritize funds for rehabilitation, modification, and/or replacement projects. The goal of the assessment and subsequent analysis is to identify potential improvements for the existing structures and treatment processes in an attempt to maximize treatment efficiency and extend the operational life of these facilities. The reports and technical memoranda generated as part of this assessment project will be used to develop a strategy for prioritizing modifications to the WTP to ensure it can efficiently and cost-effectively provide clean, potable water for the existing and projected service areas.

This memorandum includes a seismic evaluation of two buildings at the WTP and provides recommendations for improvements. These buildings are the Main Water Treatment Plant Building (Main Building) and the Finished Water Pump Building (Pump Building). Items evaluated include the structural systems of the buildings as well as nonstructural components that affect building functionality. This memorandum provides the basis and results of the seismic evaluation. The memorandum also summarizes the finding of another seismic evaluation for the Sudden Valley WTP (SVWTP) Reservoir at the WTP site.

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EXECUTIVE SUMMARY

The Main Building and Pump Building were seismically evaluated using the Tier 3 procedure of American Society of Civil Engineers (ASCE) 41 *Seismic Evaluation and Retrofit of Existing Buildings*. This procedure highlights the four seismic hazard levels and four building performance levels for building function after a seismic event, ranging from BSE-1E Collapse Prevention (least stringent) to BSE-2N Operational (most stringent). A seismic hazard level of BSE-1N and a building performance level of Operational were used as seismic design criteria for both the Main Building and the Pump Building because these levels most closely approximate the seismic requirements that would apply for these buildings if they were built under today's building code. The intent of the building performance level of Operational is very minor damage to the building structure after the design-level earthquake and no required structural repairs before reoccupancy.

Deficiencies and retrofits for the buildings are separated into two categories: structural and nonstructural. Structural refers to any part of the main structure of the building while nonstructural refers to any item that is supported from the main structure.

For the Main Building, no structural deficiencies were found so no structural retrofits are recommended. Nonstructural retrofits with an estimated construction cost of $118,000 are recommended based on seismic deficiencies identified.

For the Pump Building, structural and nonstructural retrofits with an estimated construction cost of $291,000 are recommended based on seismic deficiencies that were identified.

The SVWTP reservoir was seismically evaluated in 2016 and found to have foundation and piping flexibility deficiencies. The estimated construction cost for addressing these deficiencies is $200,000 after adjusting to 2020 dollars.

BACKGROUND AND EXISTING FACILITIES

The District operates three Group A water systems – South Shore (DOH 95910), Eagleridge (DOH 08118), and Agate Heights (DOH 52957) – all of which are in and around the shores of Lake Whatcom, which lies southeast of Bellingham in Whatcom County, Washington. The District serves approximately 3,900 residential and commercial water system connections with a residential population of approximately 10,000 people.

The South Shore system is the largest of the three systems and is supplied wholly by water treated at the District's Sudden Valley Water Treatment Plant. In addition to the WTP, the District also owns and maintains surface water source, storage, and distribution system facilities. The distribution system includes multiple pressure zones, four booster stations, and approximately 2.8 million gallons (MG) of storage in five reservoirs. The District also maintains a secondary intertie with the City of Bellingham Water System (DOH 50600) that is used only during emergency situations.

The existing WTP is a rapid-rate direct filtration plant with a rated capacity of 2.0 million gallons per day (MGD) but currently operates at approximately 1.0 MGD (700 gallons per minute (gpm)). The WTP is housed in a partially below-grade concrete building located on Morning Beach Drive approximately 1 mile northeast of the intersection of Lake Whatcom Boulevard and Marigold Drive. The facility was constructed in 1972 and has undergone several minor improvements since that time, but was most recently upgraded in 1992. The WTP provides coagulation, flocculation, filtration, disinfection, and chlorine contact time before treated water is pumped to the distribution system and storage reservoirs.

OVERVIEW OF SEISMIC HAZARDS IN THE PUGET SOUND REGION

Seismic events in the Puget Sound region can generally be categorized into three types. The first is a subduction zone mega-thrust earthquake occurring along the coastline. This type of earthquake can have the largest magnitude with Richter scale magnitudes up to and beyond M9.0 and could affect a large area of the Pacific Northwest. While this event would result in significant and destructive ground shaking in the central Puget Sound region, the highest ground shaking levels would be near the epicenter, which is located along the state's coastline. The frequency of this type of earthquake varies from approximately every 300 to 1,000 years.

The second type is a deep subduction zone earthquake. The epicenter of this type is farther inland and much deeper than the coastal mega-thrust earthquake, and Richter scale magnitudes are typically M6.0 to M7.0. The Nisqually earthquake of 2001 is an example of a deep subduction zone earthquake. These earthquakes happen approximately every 50 years.

The third type is a shallow crustal earthquake. These can happen along a variety of faults in the central Puget Sound region and can have magnitudes up to M7.5. Because the epicenters of these events are much shallower than mega-thrust and deep subduction zone earthquakes, they can cause the highest levels of ground shaking despite not having the greatest Richter scale magnitude. However, shallow crustal earthquakes affect a relatively small area as compared to subduction zone earthquakes. The Seattle Fault and

Whidbey Island Fault are examples of faults prone to shallow crustal earthquakes. The frequency of these types of events is approximately every 5,000 to 7,000 years.

Under the International Building Code (IBC) 2015, seismic design of buildings is based on a level of ground shaking that is not expected to be exceeded during a designated return interval. The return interval refers to the frequency a seismic event of a certain magnitude is expected to occur, expressed in years. The likelihood and magnitude of ground shaking from any of the three types of earthquakes previously described is used to develop maps of ground shaking parameters. To recognize the relative importance of different types of structures, an importance factor of 1.0, 1.25, or 1.50 is assigned which approximately correlate with event return intervals of 500, 1,000, and 2,500 years, respectively. Per current IBC requirements, buildings that provide essential operations and must remain in service after an earthquake are designed to the “Operational” level, with a corresponding importance factor of 1.5 and earthquake design forces correlated to the 2,500-year earthquake event.[1] This corresponds to design-level ground shaking that has a 2 percent chance of occurrence in the next 50 years, which is generally assumed to be the useful life of a building. In contrast, IBC specifies that common buildings that are not essential after an earthquake are designated to the “Life Safety” level and correspond to an importance factor of 1.0, correlating to a 500-year earthquake event. Under the Life Safety level, the building experiences damage due to the design-level earthquake, but maintains a safety factor against collapse. Repairs likely will be required before reoccupancy of the building. Life Safety is the standard for most residential and commercial structures designed today. Both the Main Building and Pump Building are evaluated to the Operational level as they are essential for continued operation of the WTP.

TIER 3 EVALUATION

After collecting information regarding the structural and nonstructural systems and components of the buildings during a site visit, Gray & Osborne performed a Tier 3 seismic analysis of the Main Building and Pump Building for the Operational performance level in accordance with ASCE 41-13 *Seismic Evaluation and Retrofit of Existing Buildings*. The Tier 3 analysis provides the most accurate results of any seismic analysis procedure stated in ASCE 41. This is due to the rigorous and in-depth calculations performed to evaluate each potential seismic deficiency. The goal of the Operational performance level is to allow occupants to survive the design-level earthquake and remain in the building safely. Continued use of the buildings should not be limited to the structural condition but may be limited by disruption of nonstructural

[1] Implied in the IBC seismic design criteria are the following two simultaneous design criteria: a Life Safety building performance level for the 2,500-year earthquake event and Operational performance level for the 500-year earthquake event.

items or processes outside of the buildings. It is important to note that the Operational performance level is approximately equivalent to the current design criteria required by the building code for new buildings designated as critical structures (Risk Category IV). In other words, if these buildings were being designed as new today, they would be designed to the Operational performance level as they are essential for continued operation of the WTP.

SEISMIC ANALYSIS CRITERIA

The Main Building and Pump Building were analyzed in accordance with the Operational performance level of ASCE 41-13 for the BSE-1N seismic hazard level. The BSE-1N seismic hazard level was chosen as the design acceleration is identical to that required by IBC 2015 for new structures. The Tier 3 analysis was used which includes detailed calculations to evaluate the adequacy of both structural and nonstructural components critical to building safety.

MAIN BUILDING SEISMIC ANALYSIS

The Main Building is constructed of cast-in-place concrete foundations, shear walls, and floors. The roof consists of prestressed concrete "T" girders with a cast-in-place topping slab. The existing components of the building were evaluated for the seismic forces determined from the accelerations for the selected seismic hazard level. Table 1 summarizes the results for each critical structural component of the Main Building. The demand/capacity ratio shown is for the most critical of each type of component. For example, all shear walls were analyzed but only reported for the most critical location. In addition, a demand/capacity ratio greater than 1.0 means the component is overstressed at the design-level forces and is likely to fail. The nonstructural elements were evaluated as well and are summarized later in the memorandum.

TABLE 1

Main Building Structural Analysis Summary

Component	Demand/Capacity Ratio
Shear Wall In-Plane Shear	0.36
Shear Wall In-Plane Flexure	0.69
Concrete Wall Out-of-Plane	0.43
Shear Wall Anchorage to Foundation	0.83
Diaphragm Shear	0.47

The results of the Tier 3 seismic analysis of the Main Building indicate that all components of the lateral force resisting system are adequate for the seismic forces corresponding to the Operational performance level. The original Tier 1 analysis identified the small embedment length of the dowels that anchor the shear walls to the foundation as a potential issue. The in-depth calculations performed as part of the Tier 3 evaluation found that the long shear walls and rigid concrete diaphragm were able to provide sufficient force distribution as to not overstress the dowels. Therefore, no structural retrofits are recommended for the Main Building.

PUMP BUILDING SEISMIC ANALYSIS

The Pump Building is constructed of masonry shear walls with wood trusses and a plywood roof topped with asphalt shingles. The existing components of the Pump Building were evaluated for the seismic forces determined from the acceleration for the selected seismic hazard level. Table 2 summarizes the results for each structural component and the demand/capacity ratio shown is for the most critical of each type of component. In addition, a demand/capacity ratio greater than 1.0 means the component is overstressed at the design-level forces and is likely to fail; these items are colored red. Table 2 shows that the diaphragm has inadequate shear capacity and that no apparent connection exists between the diaphragm and the shear walls. Each of the deficient items and associated retrofit options are discussed below.

TABLE 2

Pump Building Structural Analysis Summary

Component	Demand/Capacity Ratio
Shear Wall In-Plane Shear	0.21
Shear Wall In-Plane Flexure	0.62
CMU Wall Out-of-Plane	0.45
Shear Wall Connection to Diaphragm	__ (1)
Shear Wall Anchorage to Foundation	0.30
Diaphragm Shear	**1.63**

(1) No apparent connection exists.

Shear Wall Connection to Diaphragm

Based on the record drawings provided by the District, there is not proper detailing to transmit shear forces in the roof diaphragm to the shear wall. Observations made during the site visit confirmed this condition. This issue poses a threat of significant damage and roof collapse during an earthquake as the diaphragm is not adequately braced by the

CMU shear walls to resist horizontal movements during an earthquake. One retrofit option to address this deficiency involves removing the existing soffit at the long overhangs and replacing it with a structural diaphragm. New blocking could be installed at the fascia and new clips added at the shear walls to anchor the diaphragm. This would allow a load path for the roof diaphragm force to transfer through the soffit to the shear walls. In this option, the existing continuous vent located at the underside of the roof overhangs could be replaced with regularly spaced drilled holes to preserve continuity of sheathing between the edge of the roof and the bearing wall. At the north side of the building where there is very little overhang, the existing blocking would be removed and new vented blocking could be installed that would fasten to both the top of the wall and the underside of the roof sheathing. This would require the removal of a small area of roof sheathing in this location.

Diaphragm Shear

The record drawings did not contain complete information regarding the attachment of the roof sheathing; therefore, the diaphragm was analyzed using assumed values commonly found in this type of construction. Based on these assumptions, the existing diaphragm does not have sufficient shear strength to resist the calculated seismic forces. One option to address this issue is to remove the existing roofing down to the sheathing and install additional nails to increase the shear capacity. A new roofing system would then need to be installed. It should be noted that this retrofit is based on assumed design values. The actual construction of the diaphragm should be verified in the field and checked for consistency with the assumptions. Depending on what is discovered in the field, the diaphragm could require a more robust retrofit or possibly no retrofit at all.

NONSTRUCTURAL ANALYSIS

In addition to the seismic evaluation of the structural system, the nonstructural components were evaluated for the requirements of the Operational performance level. The goal of the nonstructural Operational performance level is for nonstructural components to be able to provide the same function post-earthquake as they provided before the earthquake. This nonstructural performance level provides a design approach for nonstructural items consistent with the design and forces of the selected structural performance level. One consideration is the potential disruption of utilities outside of the structures. If power or communications to the structures are lost, these nonstructural components may not operate. Analysis of utilities outside of the structures is beyond the scope of this evaluation. The list below contains the items covered by the nonstructural evaluation:

1. Architectural:
   a. Cladding and Glazing
   b. Partitions
   c. Ceiling Finishes
   d. Appendages and Marquees
   e. Doors and Windows

2. Mechanical Equipment:
   a. Storage Vessels
   b. Fluid Piping
   c. Fire Suppression Systems
   d. Hazardous Materials
   e. HVAC Equipment

3. Electrical and Communications Equipment:
   a. Emergency Power
   b. Light Fixtures

4. Furnishings and Interior Equipment:
   a. Storage Racks
   b. Fall-Prone Contents
   c. Computers and Communication Racks

MAIN BUILDING NONSTRUCTURAL ANALYSIS

Several nonstructural items within the Main Building were found to be noncompliant with the Operational nonstructural performance level. These items are as follows:

- Wall Framing at Restroom – Seismic bracing required.
- Wall-Mounted Transformer – Seismic bracing required.
- HVAC Unit – Seismic bracing required.
- Fluid Piping – Seismic bracing and flexible connections required.
- Electrical Panels – Seismic anchorage required.

The following retrofits are recommended to address the nonstructural deficiencies identified by the seismic evaluation:

- The wall framing at the restroom area has equipment attached to it that may result in failure of the wall during seismic shaking (Figure A-1). The proposed retrofit involves bracing the tops of the walls against the concrete ceiling of the building.

- The transformer mounted to the west wall (Figure A-2) requires seismic bracing in each lateral direction fastening back to the concrete wall in order to provide proper restraint.

- The suspended HVAC unit (Figure A-3) requires bracing in each lateral direction running back to the ceiling. These braces could consist of tension cables in all four directions or steel struts in two lateral directions.

- The fluid piping (Figure A-4) requires seismic bracing at regular spacing throughout the structure along the runs of each pipe.

- The piping from the various fluid-filled tanks (filters, flocculation tank, soda ash tank, and alum tank) that are supported from the floor of the building require flexible connections in order to mitigate any damage caused by differential movement between the tanks and the building during an earthquake. This applies to all tanks where differential movement poses a risk of significant damage.

- The electrical panels (Figure A-5) require additional seismic anchorage in order to comply with the selected performance level. This involves installing additional anchorage dowels that fasten each panel to the supporting slab to prevent any panels from overturning due to ground shaking.

These nonstructural retrofits are essential in order for the Main Building to conform to the Operational performance level. Figures A-1 through A-5 in Exhibit A show the nonstructural items that require retrofit. Estimated order-of-magnitude construction costs for these nonstructural items are provided in Exhibit C.

PUMP BUILDING NONSTRUCTURAL ANALYSIS

Several nonstructural items within the Pump Building were found to be noncompliant with the Operational nonstructural performance level. These items are as follows:

- Masonry Partition Walls – Remove and replace with wood-framed walls.
- Generator Exhaust – Seismic bracing required.
- Gas Heating Unit – Seismic bracing required.
- Natural Gas Piping – Seismic bracing required.
- Fluid Piping – Flexible connection and seismic bracing required.
- Gas Meter – Flexible connection required.

- Wall-Mounted Transformer – Seismic bracing required.
- Water Heater – Seismic restraint required.
- Conduit Runs – Seismic bracing required.
- Electrical Panels – Seismic anchorage required.

The following retrofits are recommended to address the nonstructural deficiencies identified by the seismic evaluation:

- Masonry partition walls separate the restrooms and the stalls within the restrooms. The masonry appears to be minimally reinforced, creating a high risk of collapse during an earthquake. The most efficient option to address the masonry partition walls is to remove the existing partition walls and replace them with wood-framed walls with a durable finish.

- The generator exhaust (Figure B-1) is unbraced and could become disconnected from the unit during an earthquake. The proposed retrofit is to install a brace in each lateral direction that brace it against the wall.

- The gas heating unit (Figure B-2) is unbraced and new seismic bracing should be installed in each lateral direction and attached to the ceiling.

- The natural gas piping, fluid piping, and conduit runs (Figures B-3, B-4, and B-8) require seismic bracing at regular spacing installed throughout the structure along the runs to each component.

- The gas meter (Figure B-5) just outside the structure has piping that runs from the ground through the wall of the building. Differential movement could cause this line to rupture during an earthquake. It is recommended to install a flexible coupling in the line to accommodate any movement.

- The transformer mounted on the north interior wall (Figure B-6) may shake loose during an earthquake. The proposed retrofit is to install lateral bracing back to the walls.

- The water heater (Figure B-7) does not appear to be properly restrained. It is recommended that the water heater be strapped to the adjacent wall.

- The electrical panels in the building (Figure B-9) require additional seismic anchorage in order to comply with the selected performance level. This involves installing additional dowels that fasten each panel to the supporting slab to prevent the panels from overturning.

These nonstructural retrofits are essential in order for the Pump Building to conform to the Operational performance level. Figures B-1 through B-9 in Exhibit B show the nonstructural items that require retrofit. Estimated order-of-magnitude construction costs for these nonstructural items are provided in Exhibit C.

SEISMIC RETROFIT SUMMARY

We recommend that the District complete the seismic retrofits described in order to ensure that the Main Building and Pump Building meet criteria listed for the Operational performance level. Some items for which seismic retrofits are recommended may be slated for replacement in the next 5 to 10 years. For these items, the District may consider not installing the recommended seismic retrofits and accepting a relatively small risk of a design-level earthquake occurring prior to the planned replacement of the item.

The recommended modifications for the Main Building are estimated to cost $118,000, which includes materials, installation, contingency (20 percent), Washington State sales tax (9.0 percent), and design and project administration (25 percent). A complete budgetary cost estimate is provided in Exhibit C.

The recommended modifications for the Pump Building are estimated to cost $291,000, which includes materials, installation, contingency (20 percent), Washington State sales tax (9.0 percent), and design and project administration (25 percent). A complete budgetary cost estimate is provided in Exhibit C.

SVWTP RESERVOIR SUMMARY

In the December 2016 report “Lake Whatcom Water and Sewer District Reservoir Seismic Vulnerability Assessment Technical Report” by BHC Consultants, a seismic evaluation of the WTP Reservoir was performed. The evaluation found the shell, foundation, and anchorage to be adequate for the predicted seismic forces. The two deficiencies identified were inadequate uplift resistance of the foundation and lack of piping flexibility. The retrofit recommended in the report to address the foundation uplift deficiency is to construct a widened foundation ring wall. To address the lack of flexible piping, it is recommended in the report that force-balanced FLEX-TEND® couplings be installed. The report estimates the cost of these retrofits to be $156,000. After applying 4 years of construction cost escalation, the estimate increases to $200,000 which includes materials, contingency, Washington State sales tax, and design/project administration.

EXHIBIT A

MAIN BUILDING PHOTOS

FIGURE A-1

Restroom Wall Framing

FIGURE A-2

Wall-Mounted Transformer

FIGURE A-3

HVAC Unit

FIGURE A-4

Fluid Piping

FIGURE A-5

Electrical Panels

EXHIBIT B

PUMP BUILDING PHOTOS

FIGURE B-1

Generator Exhaust

FIGURE B-2

Gas Heating Unit

FIGURE B-3

Natural Gas Piping

FIGURE B-4

Fluid Piping

FIGURE B-5

Gas Meter

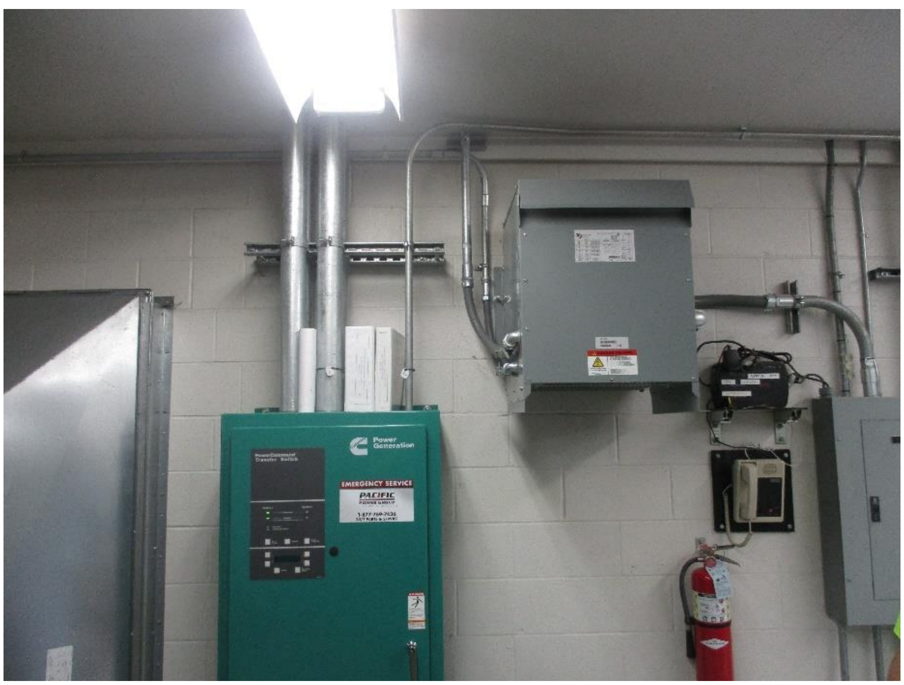

FIGURE B-6

Wall-Mounted Transformer

FIGURE B-7

Water Heater

FIGURE B-8

Conduit Runs

FIGURE B-9

Electrical Panels

EXHIBIT C

SEISMIC RETROFIT COST ESTIMATES

LAKE WHATCOM WATER AND SEWER DISTRICT

SUDDEN VALLEY WTP ASSESSMENT AND ALTERNATIVES ANALYSIS PROJECT
PRELIMINARY COST ESTIMATE

Technical Memorandum 20434-3 - Recommended Main Building Seismic Retrofits
October 6, 2020
G&O# 20434.00

NO.	ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
1	Restroom wall framing - Bracing	1	LS	$ 7,000	$ 7,000
2	Wall mounted transformer – Bracing	1	LS	$ 4,000	$ 4,000
3	HVAC unit – Bracing	1	LS	$ 4,000	$ 4,000
4	Fluid piping – Bracing	1	LS	$ 20,000	$ 20,000
5	Fluid piping – Flexible connections	1	LS	$ 30,000	$ 30,000
6	Electrical panels - Anchorage	1	LS	$ 7,000	$ 7,000

Subtotal*	**$ 72,000**
Contingency (20%)	$ 14,400
Subtotal	**$ 86,400**
Washington State Sales Tax (9.0%)**	$ 7,800
Subtotal	**$ 94,200**
Design and Project Administration (25.0%)***	$ 23,600
TOTAL CONSTRUCTION COST	**$ 118,000**

* Costs listed are in 2020 dollars
** Current sales tax rate is 8.7%.
*** Standard project design and administration fees are 25% of the subtotal including contingency

LAKE WHATCOM WATER AND SEWER DISTRICT

SUDDEN VALLEY WTP ASSESSMENT AND ALTERNATIVES ANALYSIS PROJECT
PRELIMINARY COST ESTIMATE

Technical Memorandum 20434-3 - Recommended Pump Building Seismic Retrofits
October 6, 2020
G&O# 20434.00

NO.	ITEM	QUANTITY	UNIT	UNIT PRICE		AMOUNT	
1	Shear wall – Connection to diaphragm	1	LS	$	18,000	$	18,000
2	Diaphragm – Shear nailing	1	LS	$	25,000	$	25,000
3	Roof replacement	1	LS	$	60,000	$	60,000
4	Masonry partition walls – Replace	1	LS	$	20,000	$	20,000
5	Generator exhaust - Bracing	1	LS	$	3,000	$	3,000
6	Gas heater – Bracing	1	LS	$	3,000	$	3,000
7	Natural gas piping – Bracing	1	LS	$	6,000	$	6,000
8	Wall mounted transformer – Bracing	1	LS	$	3,000	$	3,000
9	Fluid piping – Bracing	1	LS	$	7,000	$	7,000
10	Fluid piping – Flexible connections	1	LS	$	15,000	$	15,000
10	Gas meter – Flexible connection	1	LS	$	5,000	$	5,000
11	Water heater – Add restraint	1	LS	$	2,000	$	2,000
11	Conduit – Bracing	1	LS	$	5,000	$	5,000
12	Electrical panels - Anchorage	1	LS	$	6,000	$	6,000
					Subtotal*	**$**	**178,000**
					Contingency (20%)	$	35,600
					Subtotal	**$**	**213,600**
					Washington State Sales Tax (9.0%)**	$	19,200
					Subtotal	**$**	**232,800**
					Design and Project Administration (25.0%)***	$	58,200
					TOTAL CONSTRUCTION COST	**$**	**291,000**

* Costs listed are in 2020 dollars
** Current sales tax rate is 8.7%.
*** Standard project design and administration fees are 25% of the subtotal including contingency and tax