APPENDIX A – FACILITIES EVALUATED BY REID MIDDLETON

Building and Other Structures

- August Pump Station and Gatehouse
- Boulevard Park Well and Chlorination Building
- Broadway Pump Station and Chlorination Building
- Burien Pump Station
- First Hill Pump Station
- Highland Park Pump Station
- Lake Youngs Pump Station (new)
- Lake Youngs Treatment Plant
    - Operations Building
    - Lake Youngs Intake and Raw Water Pump Station
    - Lake Youngs Ozone Generation and Injection Building
    - UV and Chemical Building
- Landsburg Tunnel Gatehouse
- Maple Leaf P.S. and Gatehouse
- Operations and Control Center
    - Administration Building (OCC)
    - Warehouse (OCC)
    - Flammable Liquid Storage (OCC)
    - Pipe Carpentry Shop (OCC)
    - Vehicle Maintenance Bldg (OCC)
    - Meter Shop (OCC)
- Riverton Well and Chlorination Building
- Tolt Filtration Plant:
    - Administration Building
    - Filter Gallery
    - Ozone Room/Contact Tank
- Warren Avenue Pump Station
- West Seattle Pump Station

Concrete and Earthen Reservoirs

- Eastside
- Lake Forest Park
- Lake Youngs Clearwells (North and South)
- Lincoln Reservoir
- Magnolia Reservoir
- Riverton Heights
- Soos North
- Soos South
- Tolt Clearwell
- View Ridge

Ground-Supported and Elevated Steel Tanks

- Charleston Standpipe
- Control Works Tanks (North and South)
- Foy Standpipe
- Richmond Highland #2 Elevated Tank
- Trenton Tanks (North and South)
- Trenton Tank South

APPENDIX B – HYDRAULIC MODELING RESULTS

M7.0 Seattle Fault Zone Base Case (No Improvements) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets
Water Distribution System Seismic Modeling
2/2/2018

Seattle Fault Seismic Event

Base No system modifications

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	250,512	230,344	20,168	71%	232.1
3	228,115	211,496	16,619	62%	186.3
12	178,256	164,131	14,126	45%	77.7
16	54,565	50,885	3,680	7%	40.8
22	24,329	23,595	734	4%	15.4
32	21,286	21,286	-	3%	3.7
48	-	-	-	2%	0.5

Model Regions Forced Out of Service During Simulation

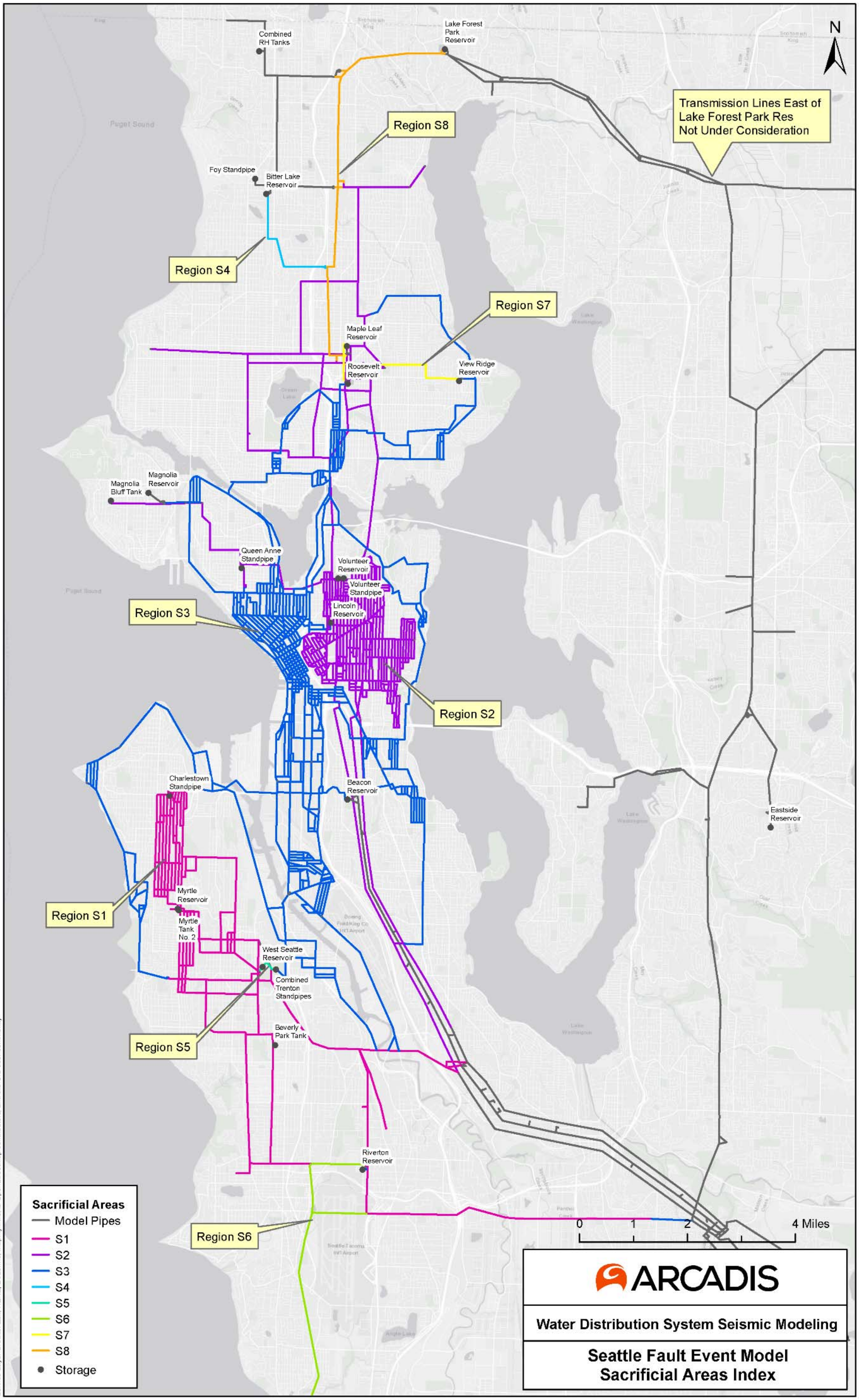
Time	Region
3	S1
15	S2
21	S3
32	S4

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 1	Hr 0	Fig. 5	Hr 8	Fig. 9	Hr 16	Fig. 13	Hr 24	Fig. 17	Hr 40
Fig. 2	Hr 2	Fig. 6	Hr 10	Fig. 10	Hr 18	Fig. 14	Hr 28	Fig. 18	Hr 44
Fig. 3	Hr 4	Fig. 7	Hr 12	Fig. 11	Hr 20	Fig. 15	Hr 32	Fig. 19	Hr 48
Fig. 4	Hr 6	Fig. 8	Hr 14	Fig. 12	Hr 22	Fig. 16	Hr 36		



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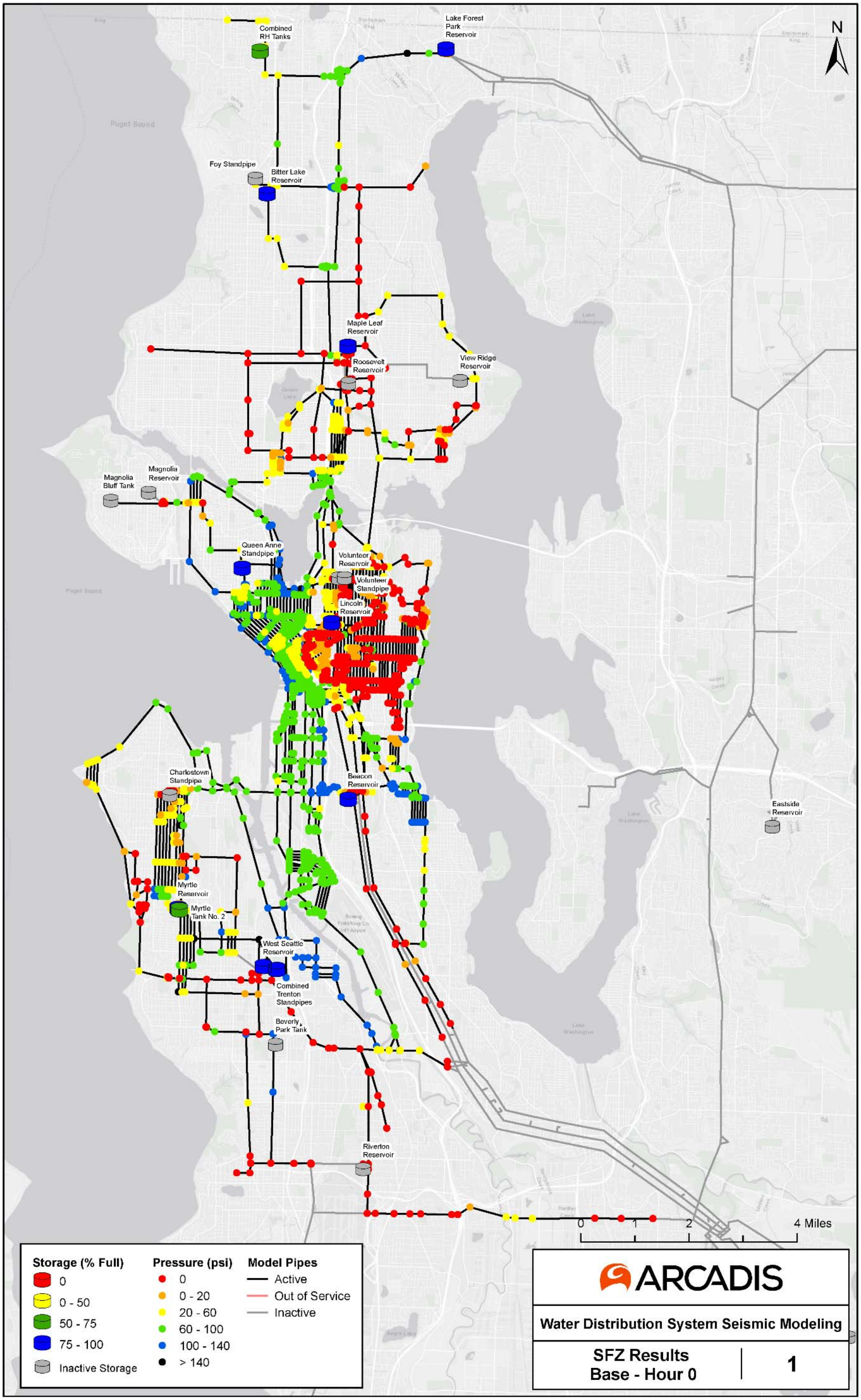

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Combined RH Tanks
Lake Forest Park Reservoir
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Puget Sound
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
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0 - 20
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Model Pipes
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Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Base - Hour 0
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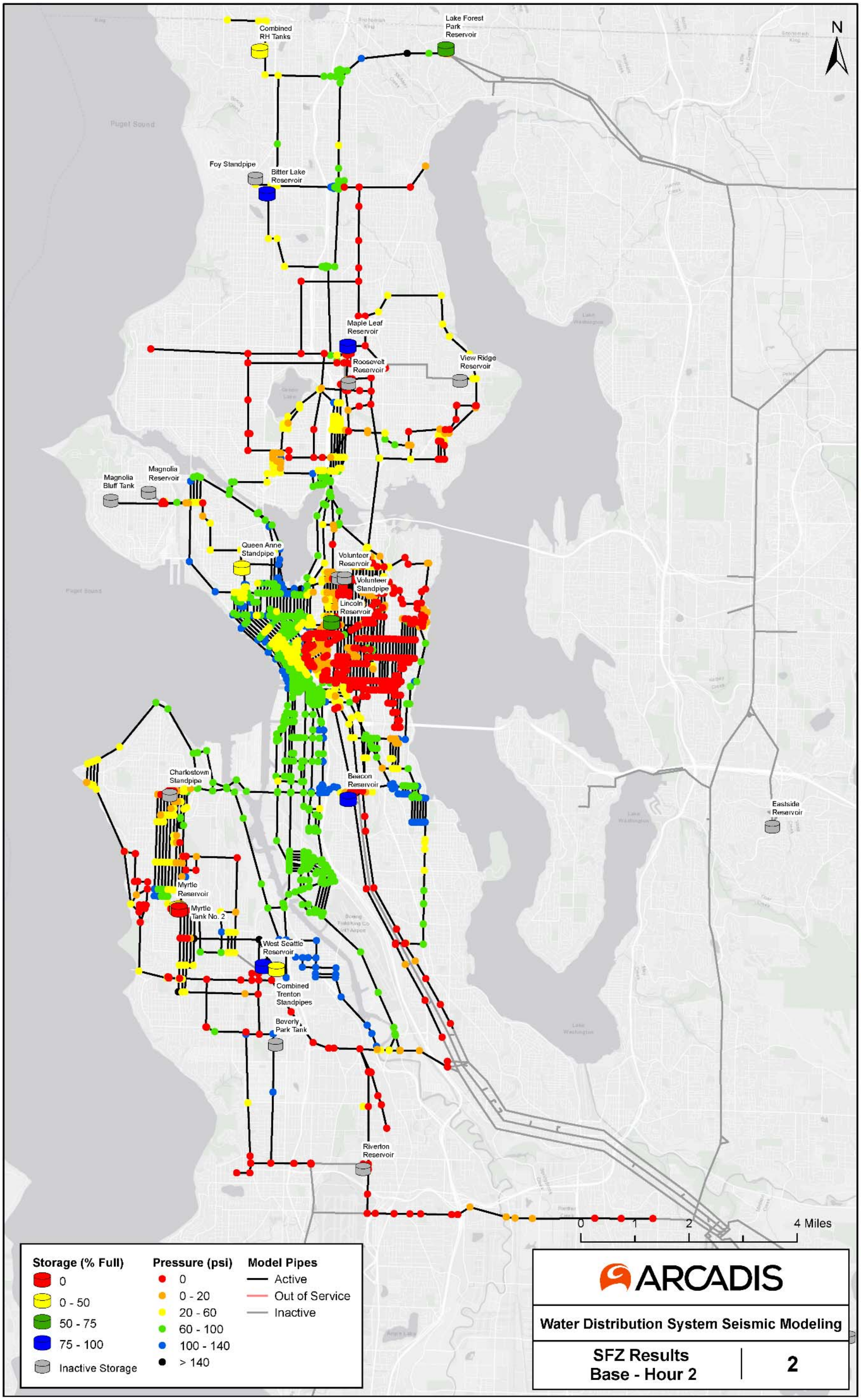
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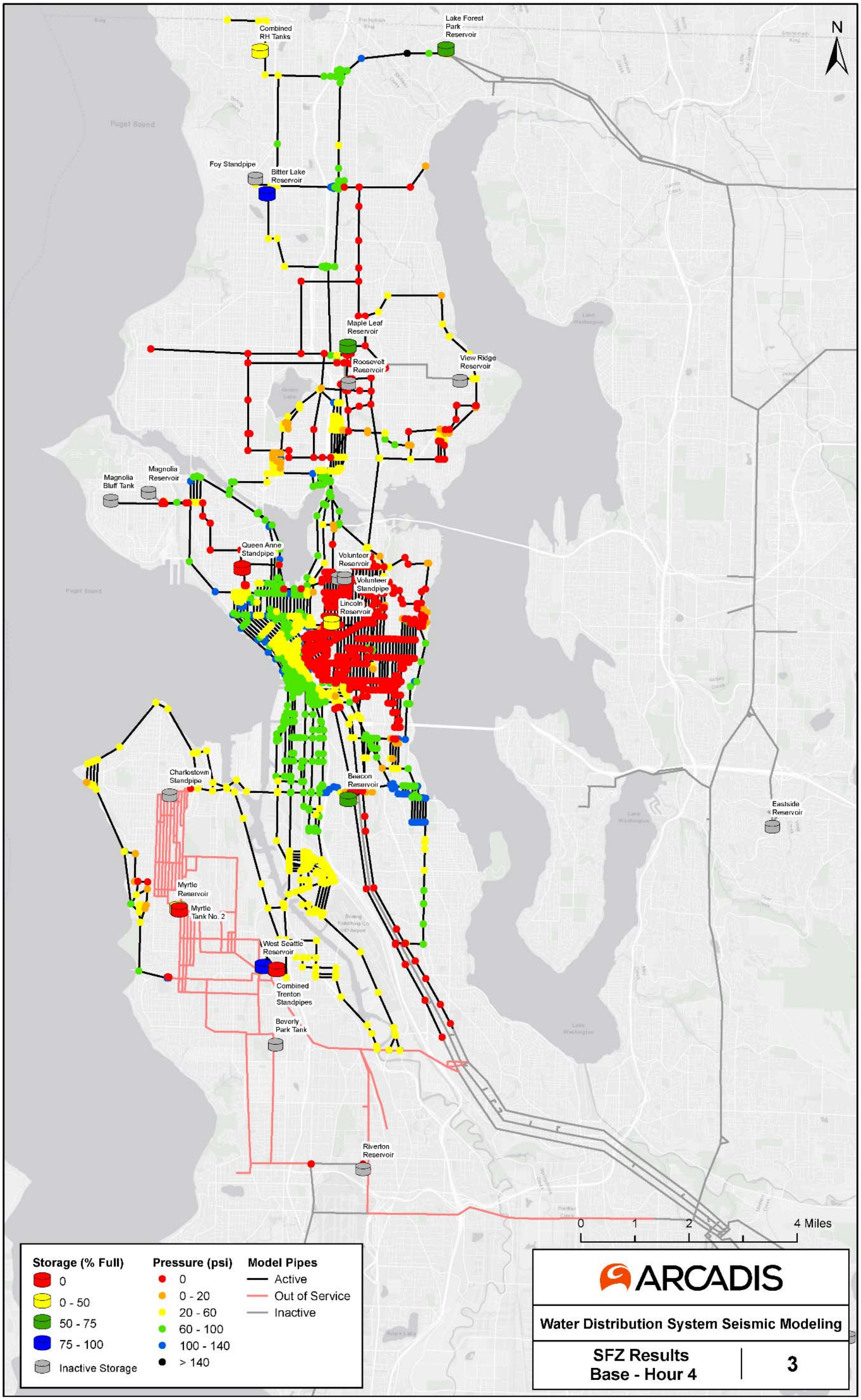

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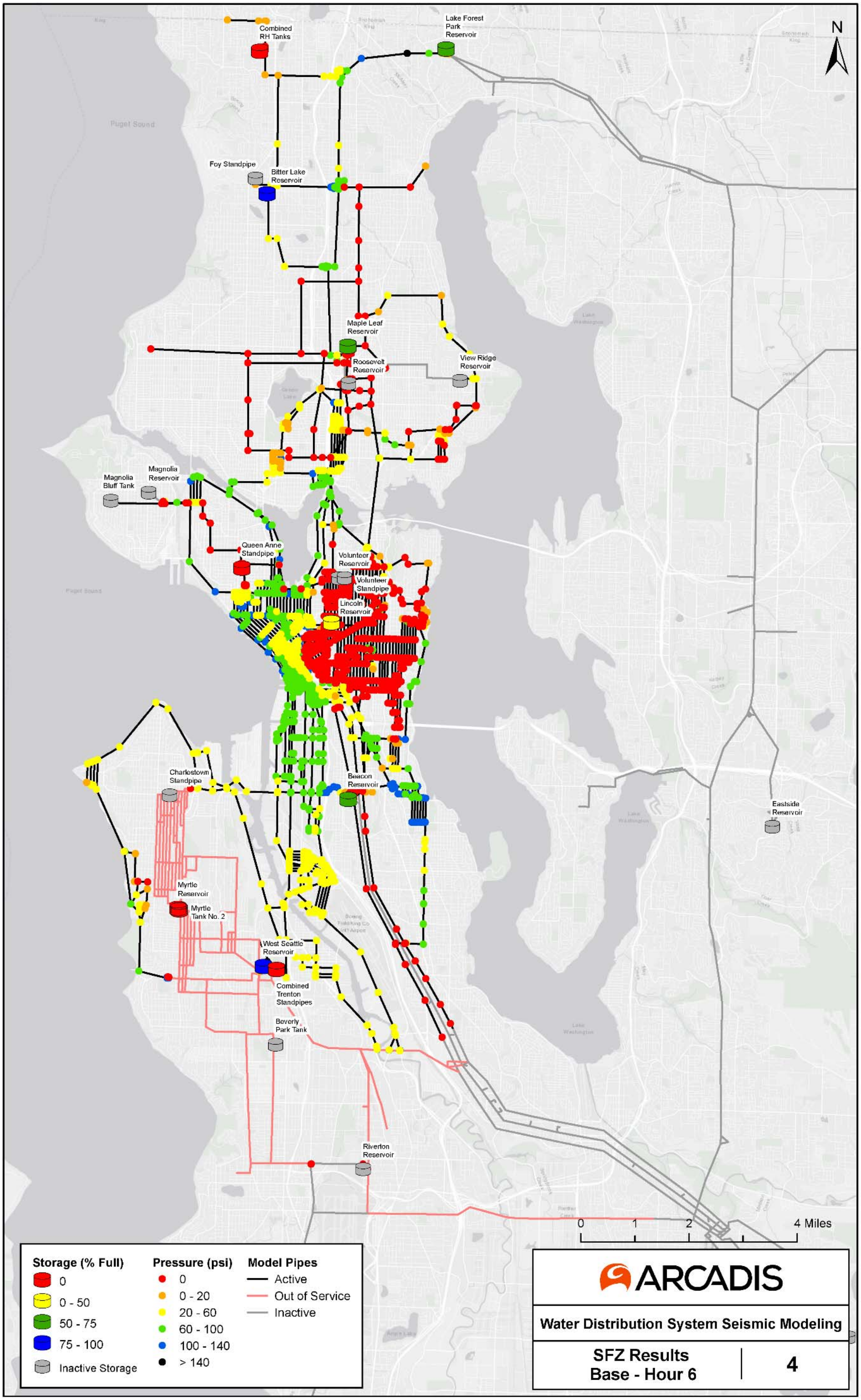

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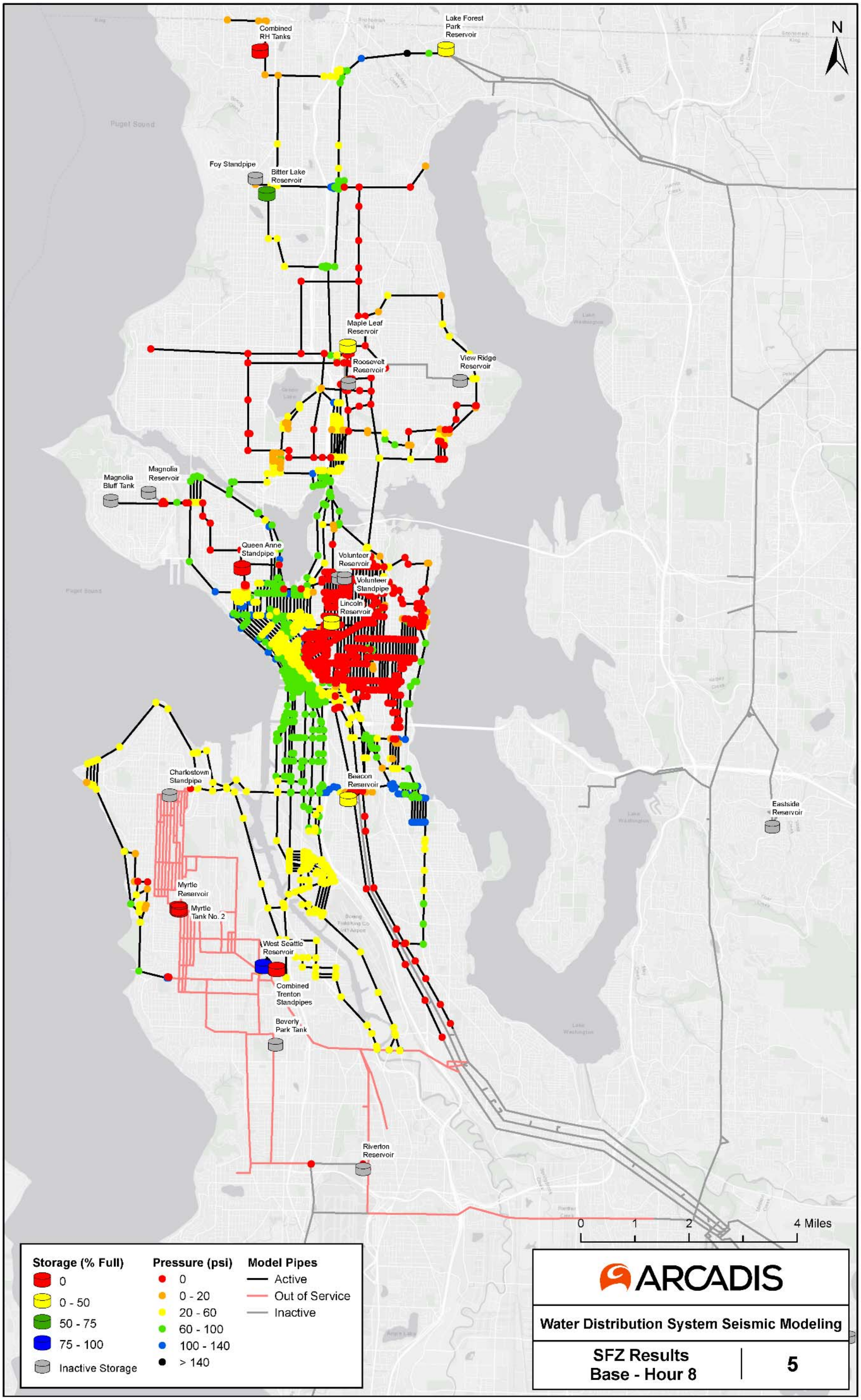

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SFZ Results
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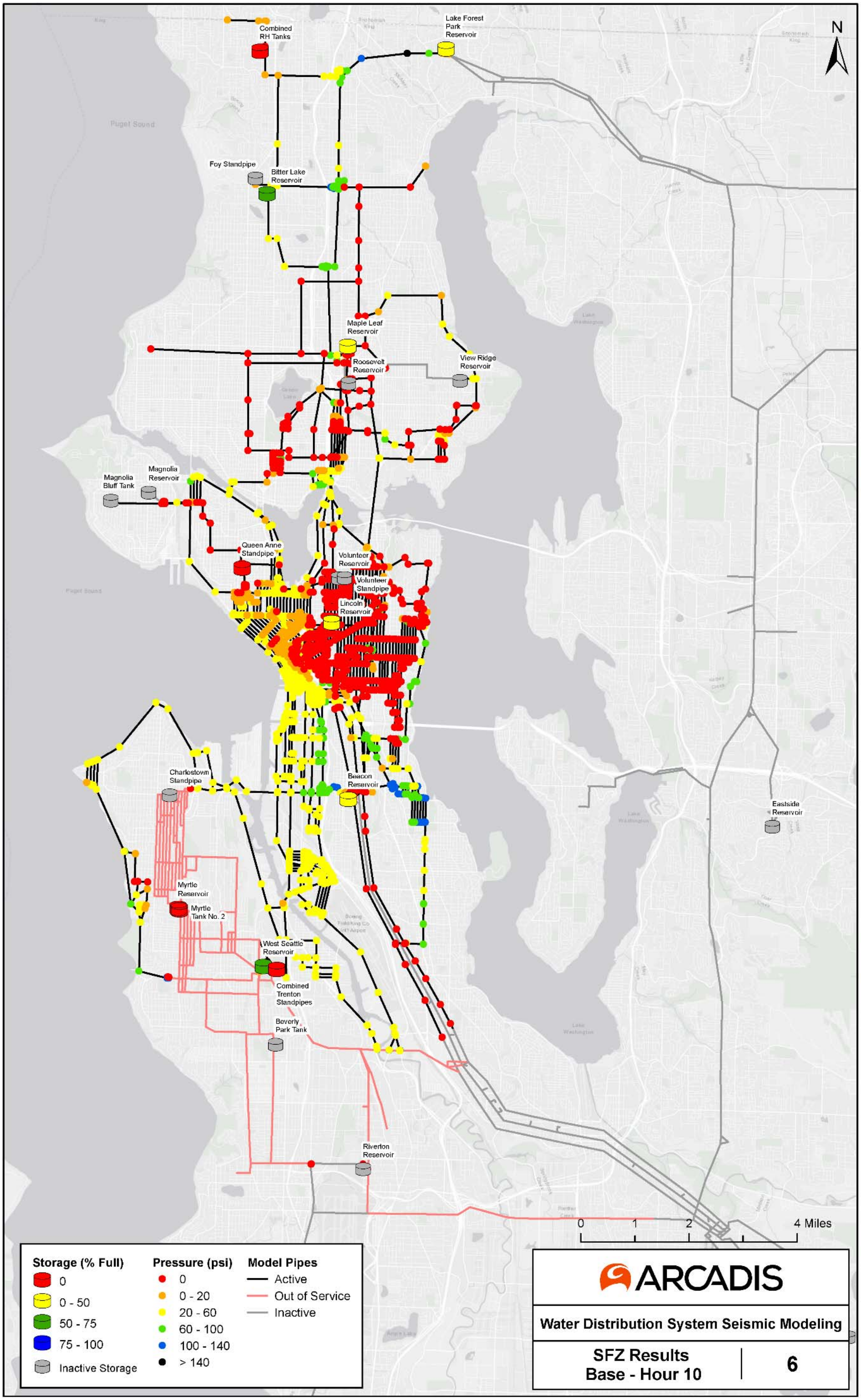

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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
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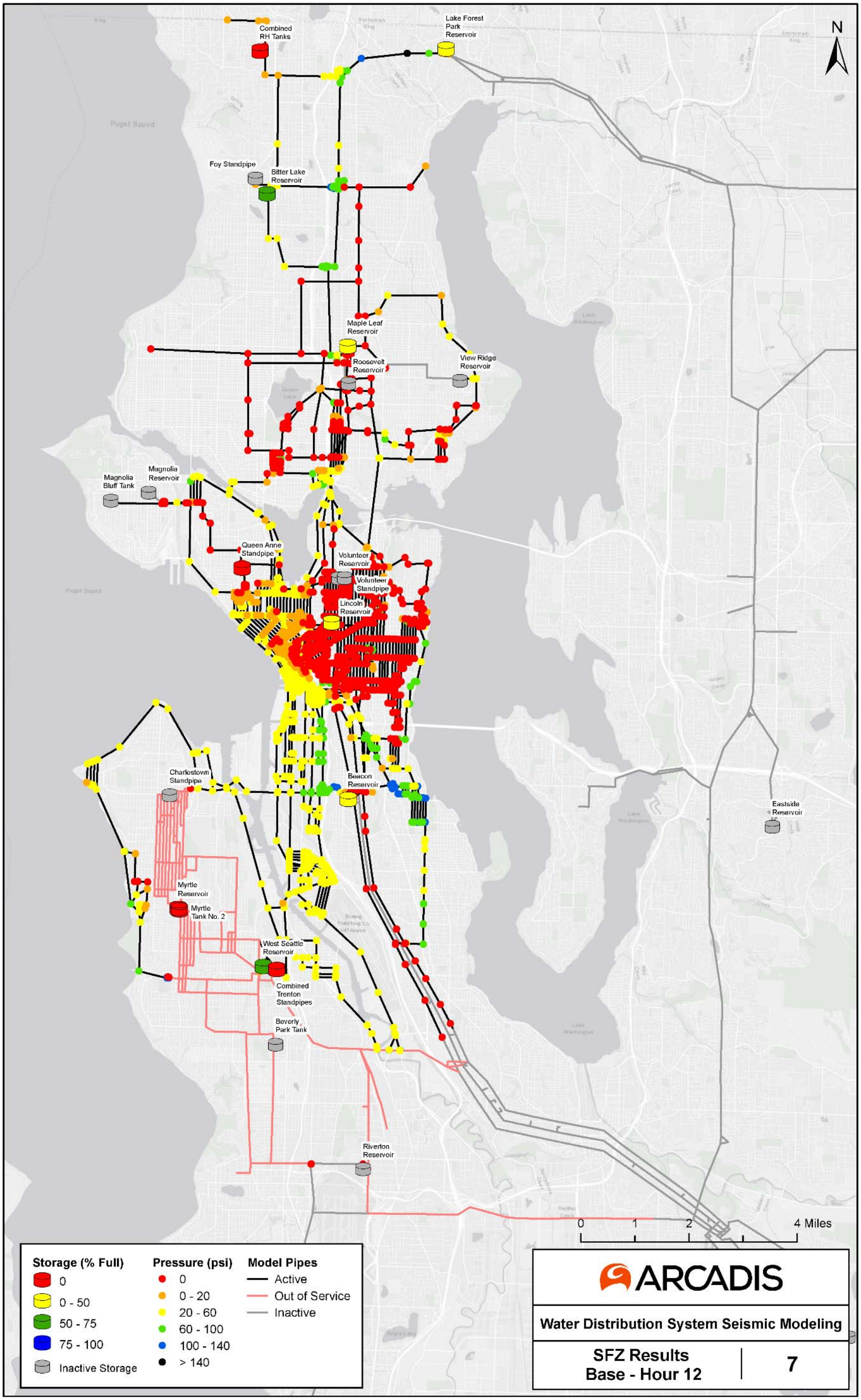
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SFZ Results
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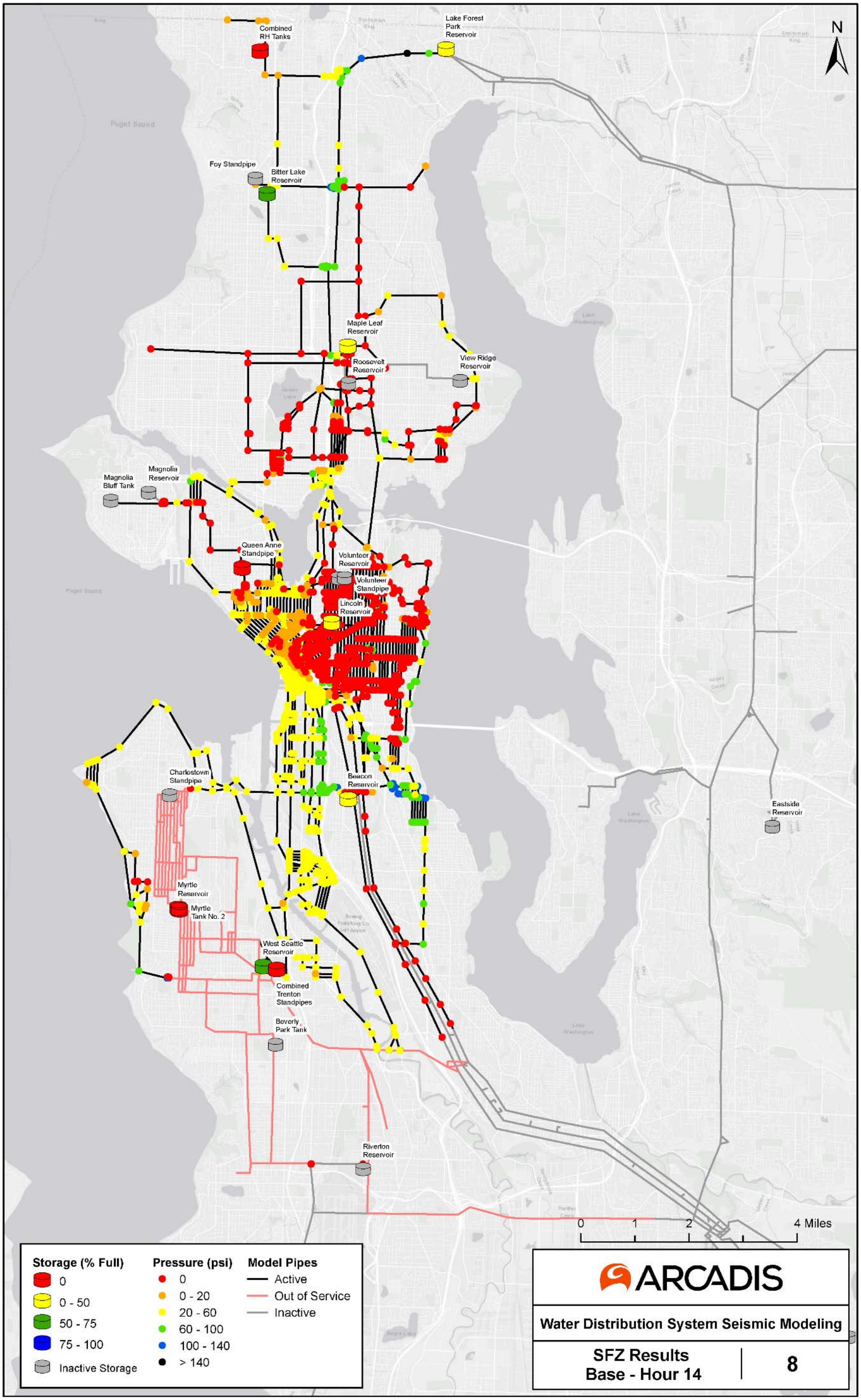
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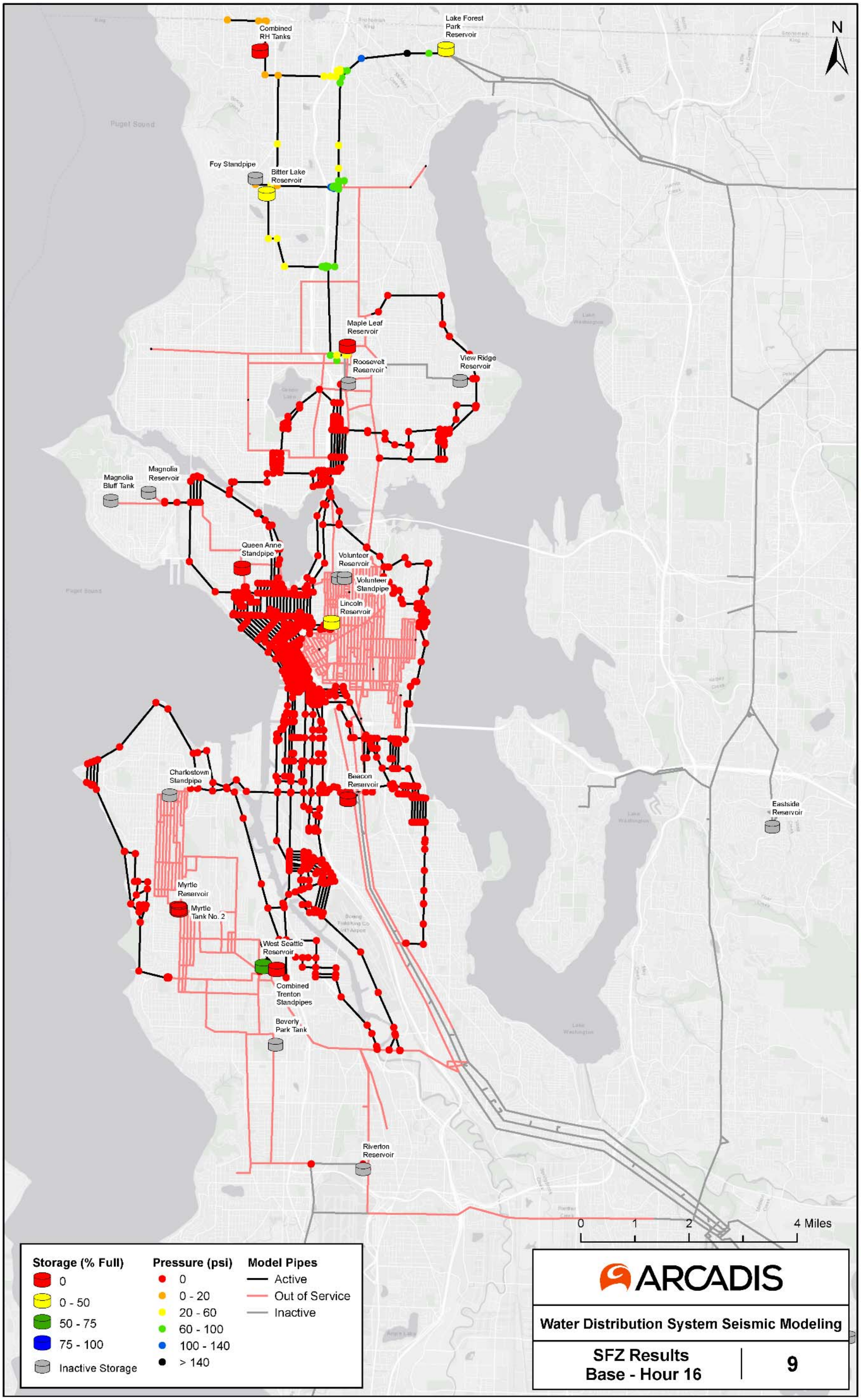
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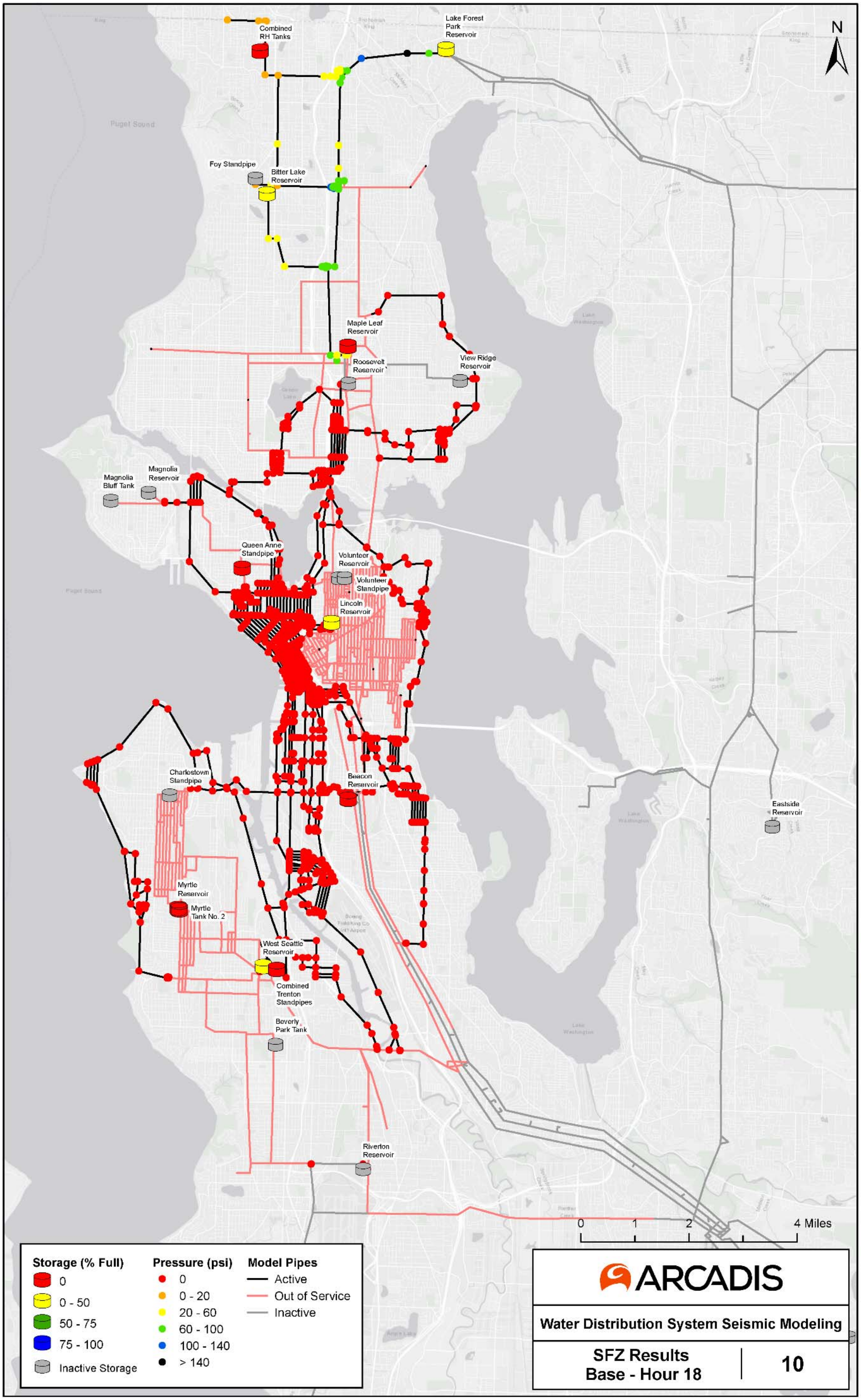

Water Distribution System Seismic Modeling

SFZ Results
Base - Hour 18

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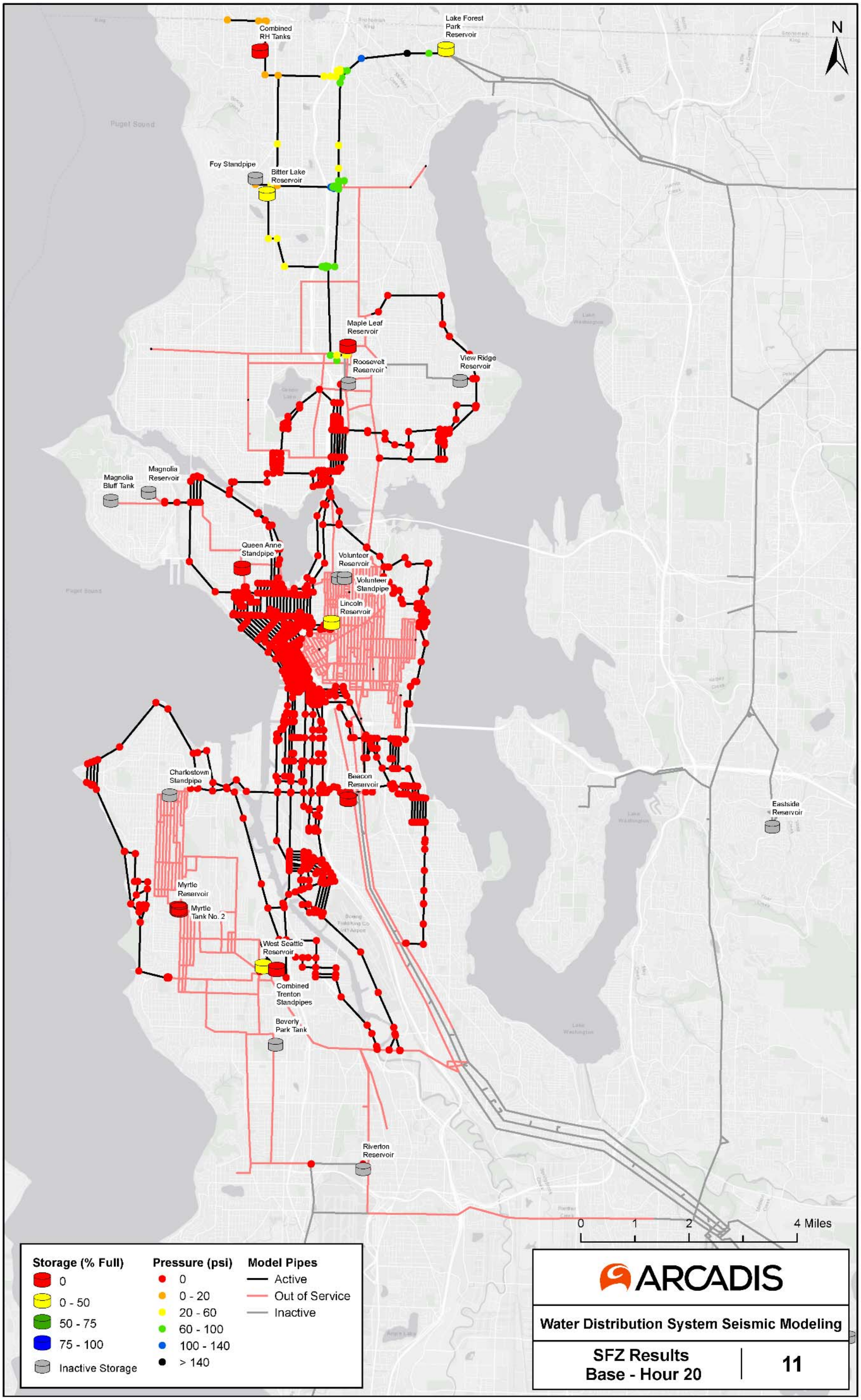
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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Base - Hour 20
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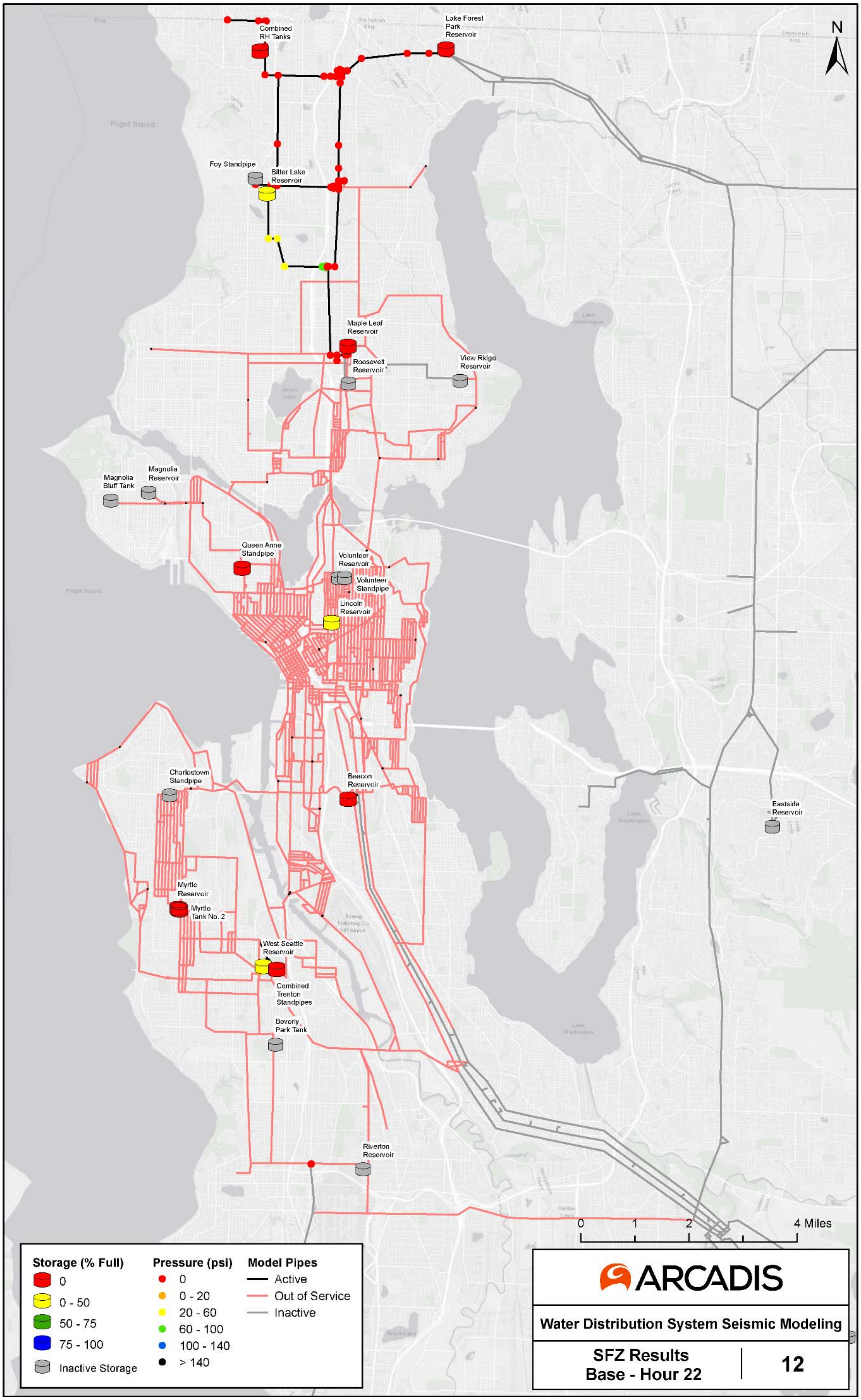
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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
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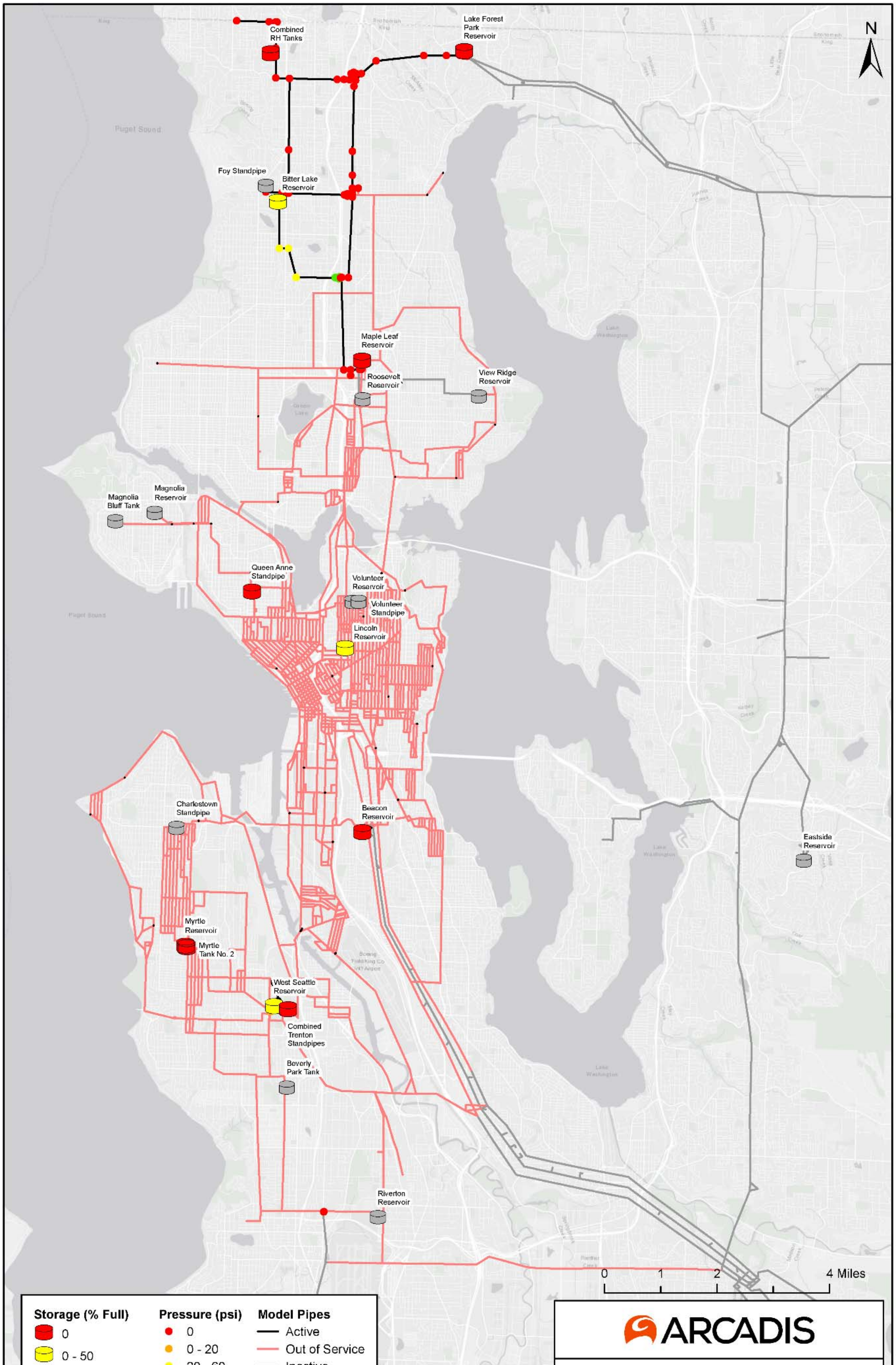

ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Base - Hour 24

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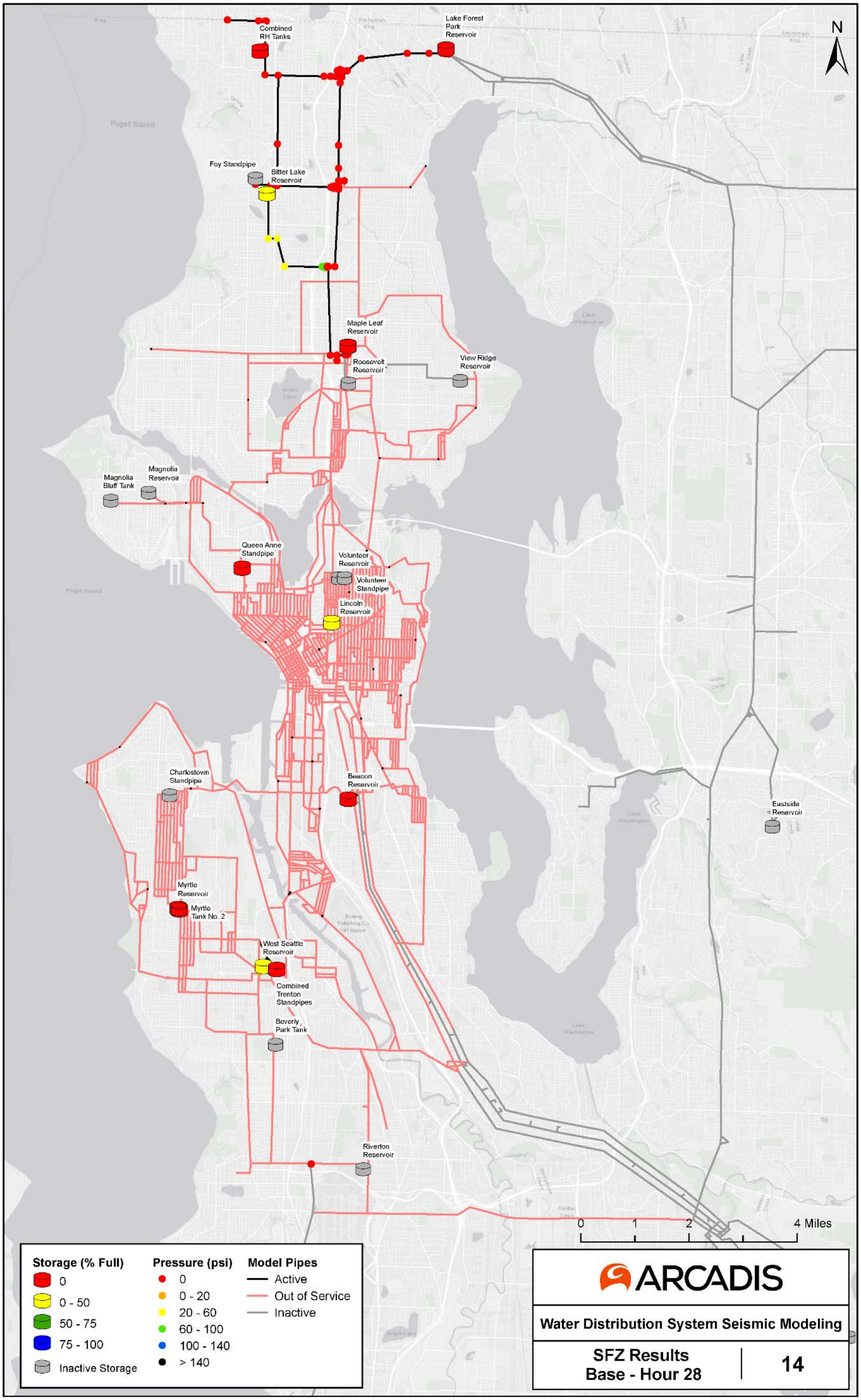

Water Distribution System Seismic Modeling

SFZ Results
Base - Hour 28

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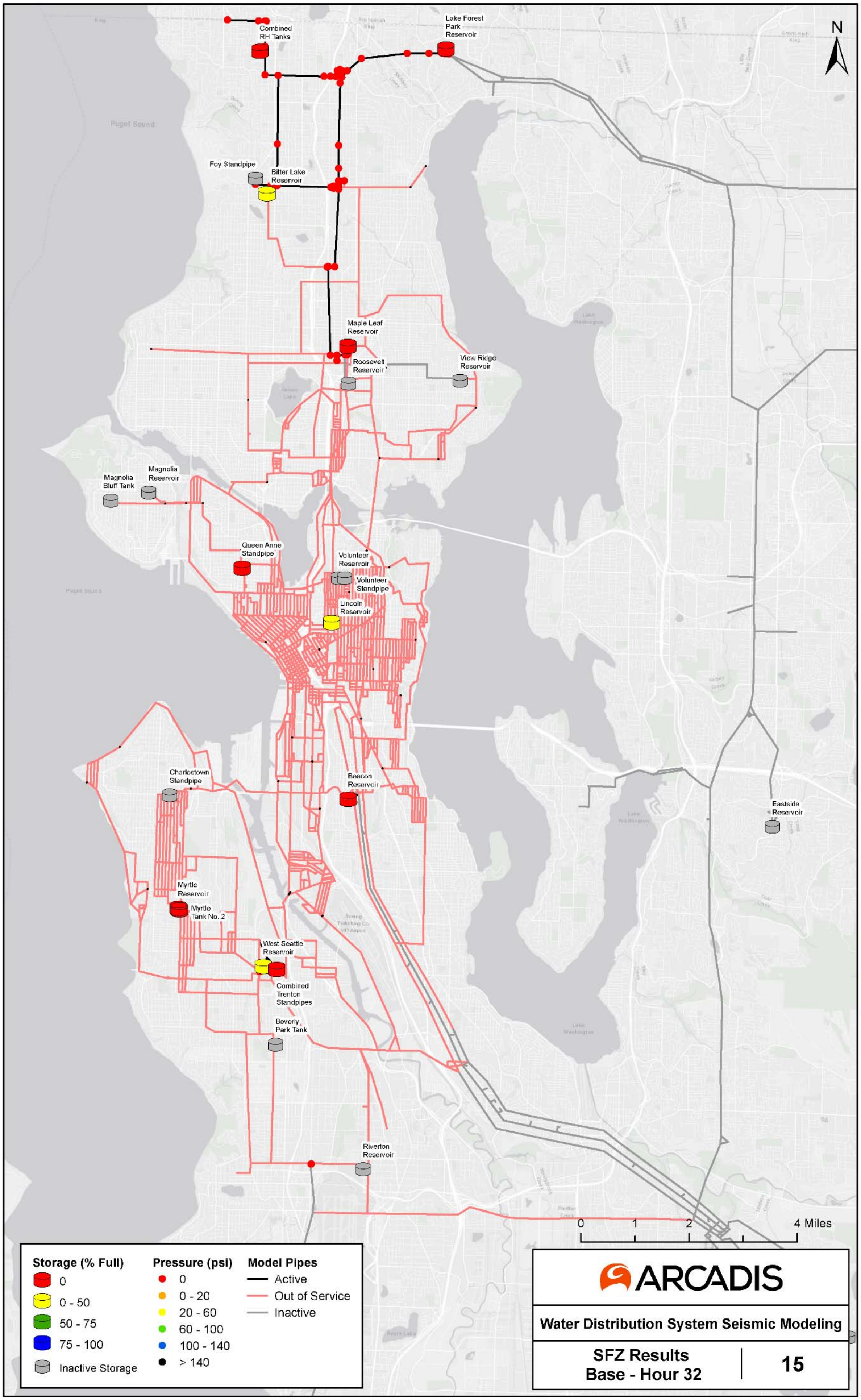

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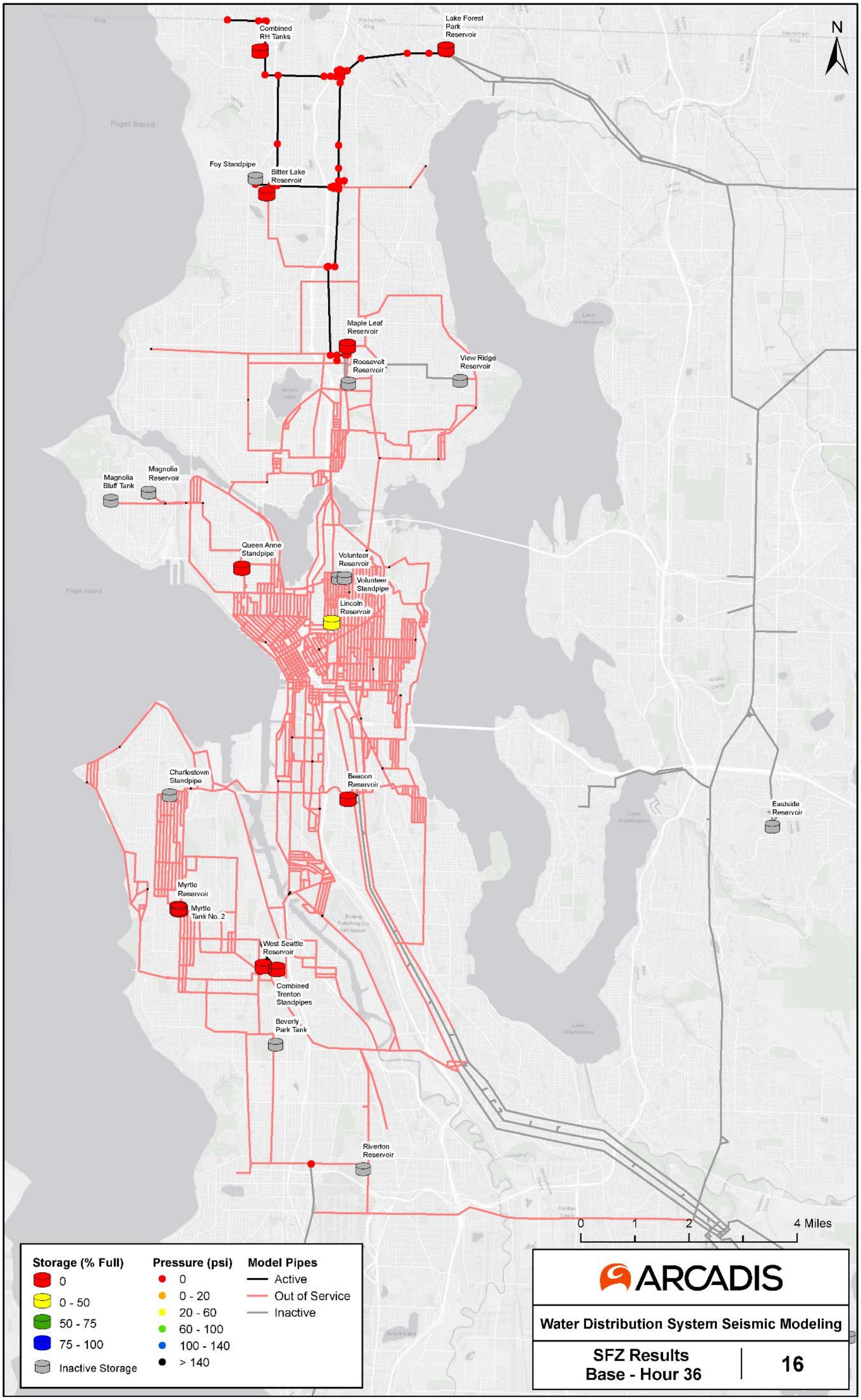
Water Distribution System Seismic Modeling

SFZ Results
Base - Hour 32



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Water Distribution System Seismic Modeling

SFZ Results
Base - Hour 36

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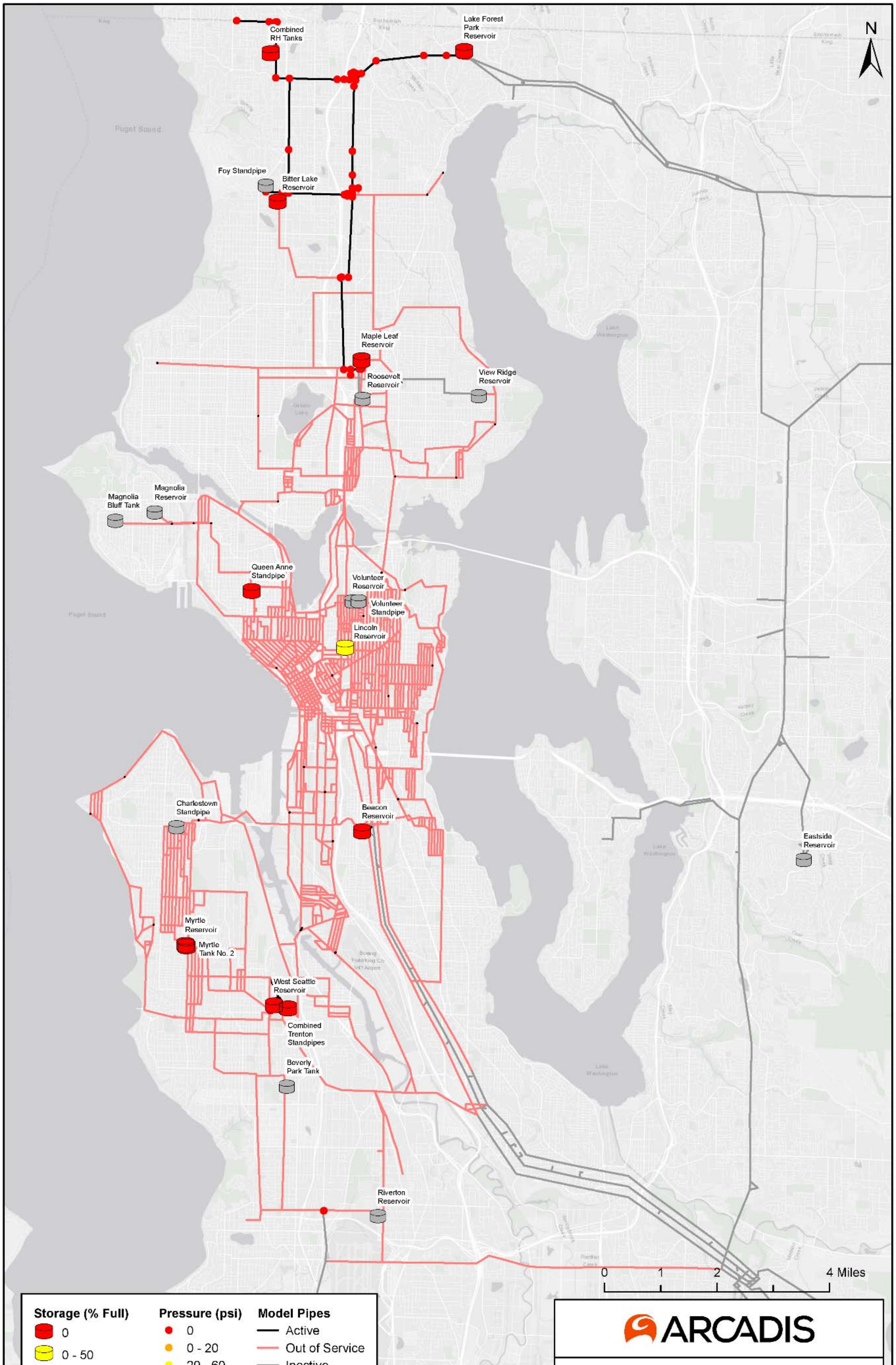
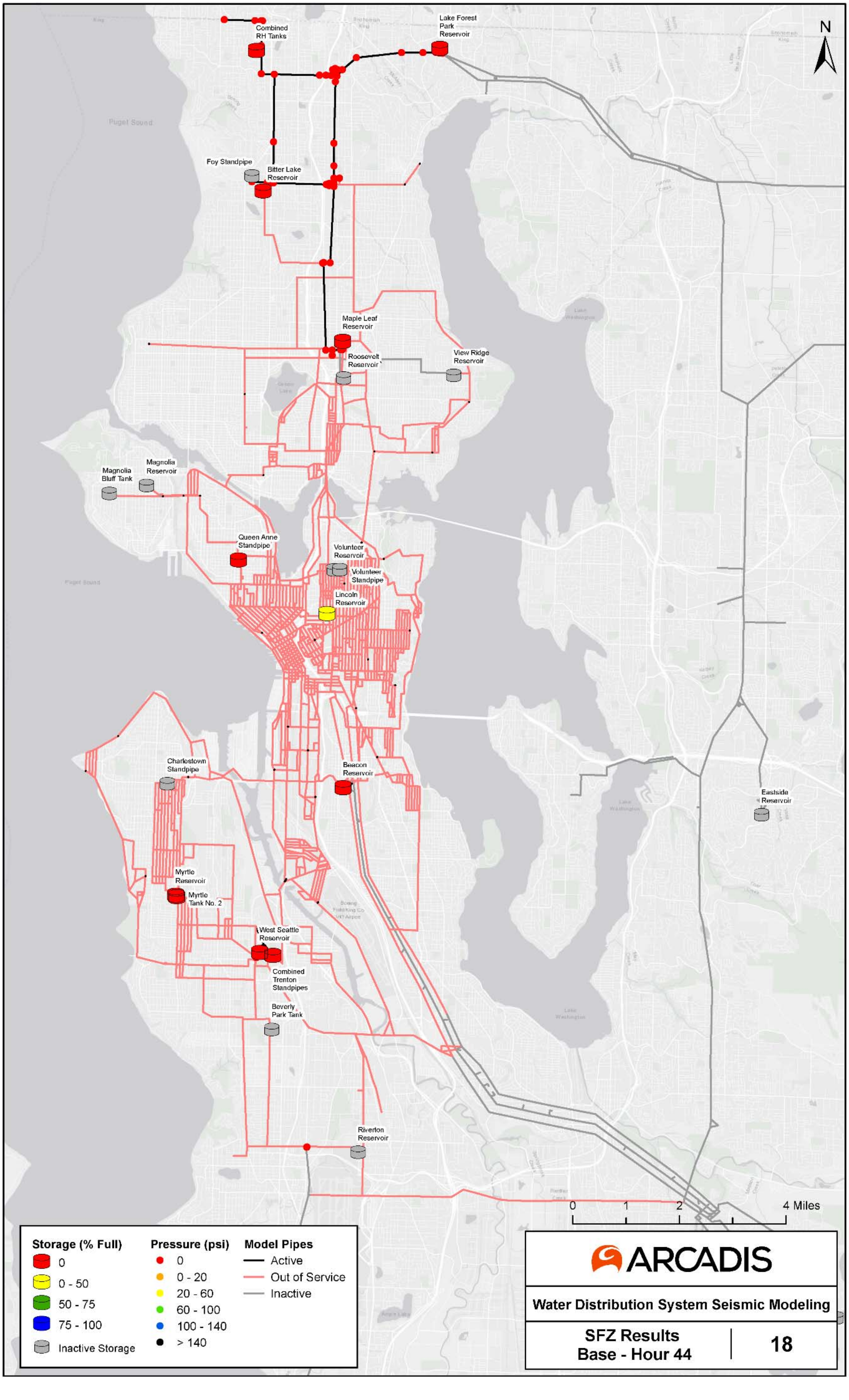


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results Base - Hour 40	17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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
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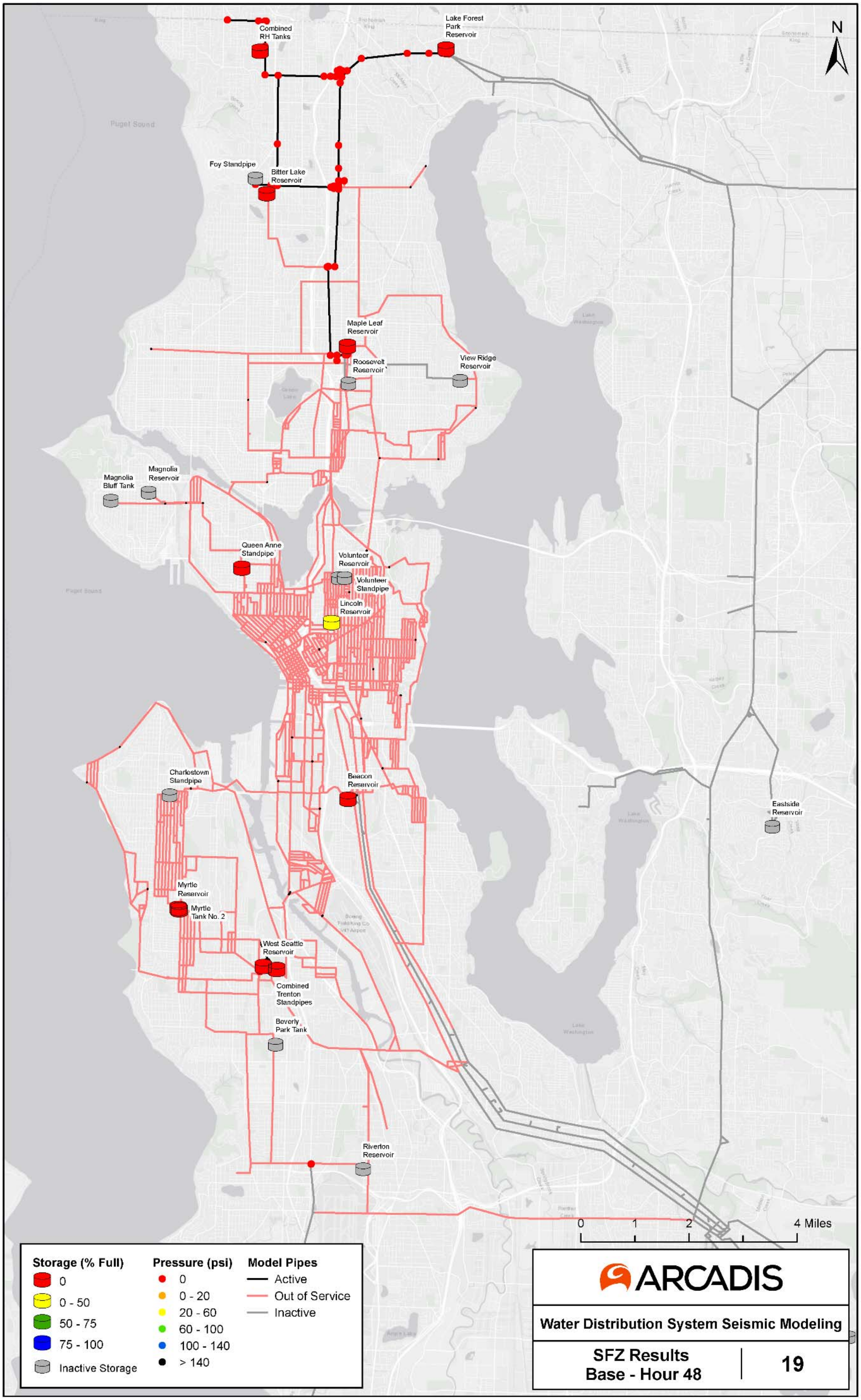
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ARCADIS
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SFZ Results
Base - Hour 48
19

M9.0 Cascadia Subduction Zone Base Case (No Improvements) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets
Water Distribution System Seismic Modeling
3/21/2018

Cascadia Seismic Event

Base No system modifications

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Satisfied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	236,361	214,034	22,326	77%	270.8
3	228,503	206,337	22,166	76%	228.4
12	182,743	164,714	18,029	60%	118.7
17	106,508	94,253	12,255	31%	61.1
22	20,590	20,590	-	2%	39.5
32	-	-	-	2%	38.6
48	-	-	-	2%	38.6

Model Regions Forced Out of Service During Simulation

Time	Region
16	C1
17	C3
20	C2

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

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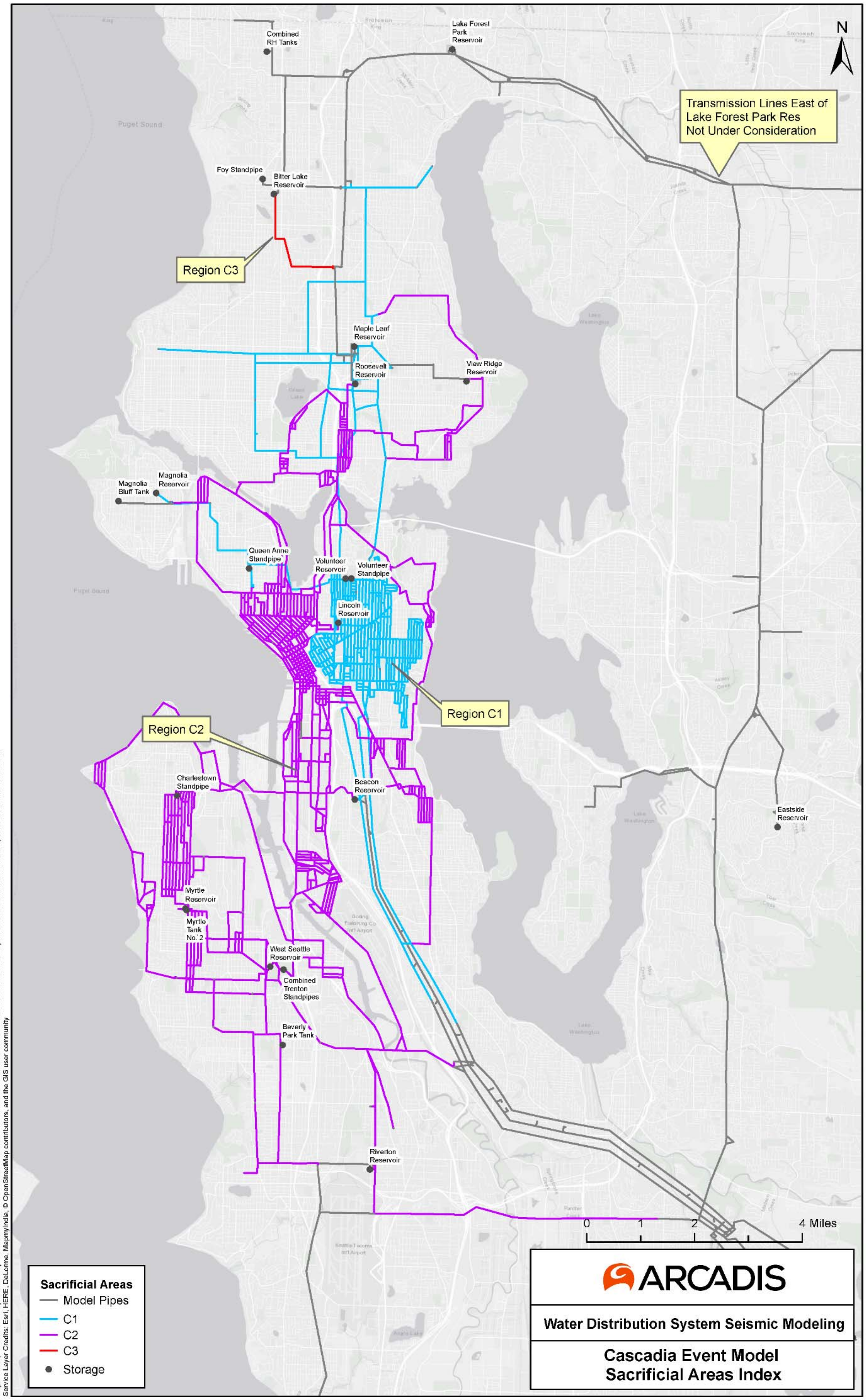
Fig. 3	Hr 4	Fig. 7	Hr 12	Fig. 11	Hr 20		
Fig. 4	Hr 6	Fig. 8	Hr 14	Fig. 12	Hr 22		



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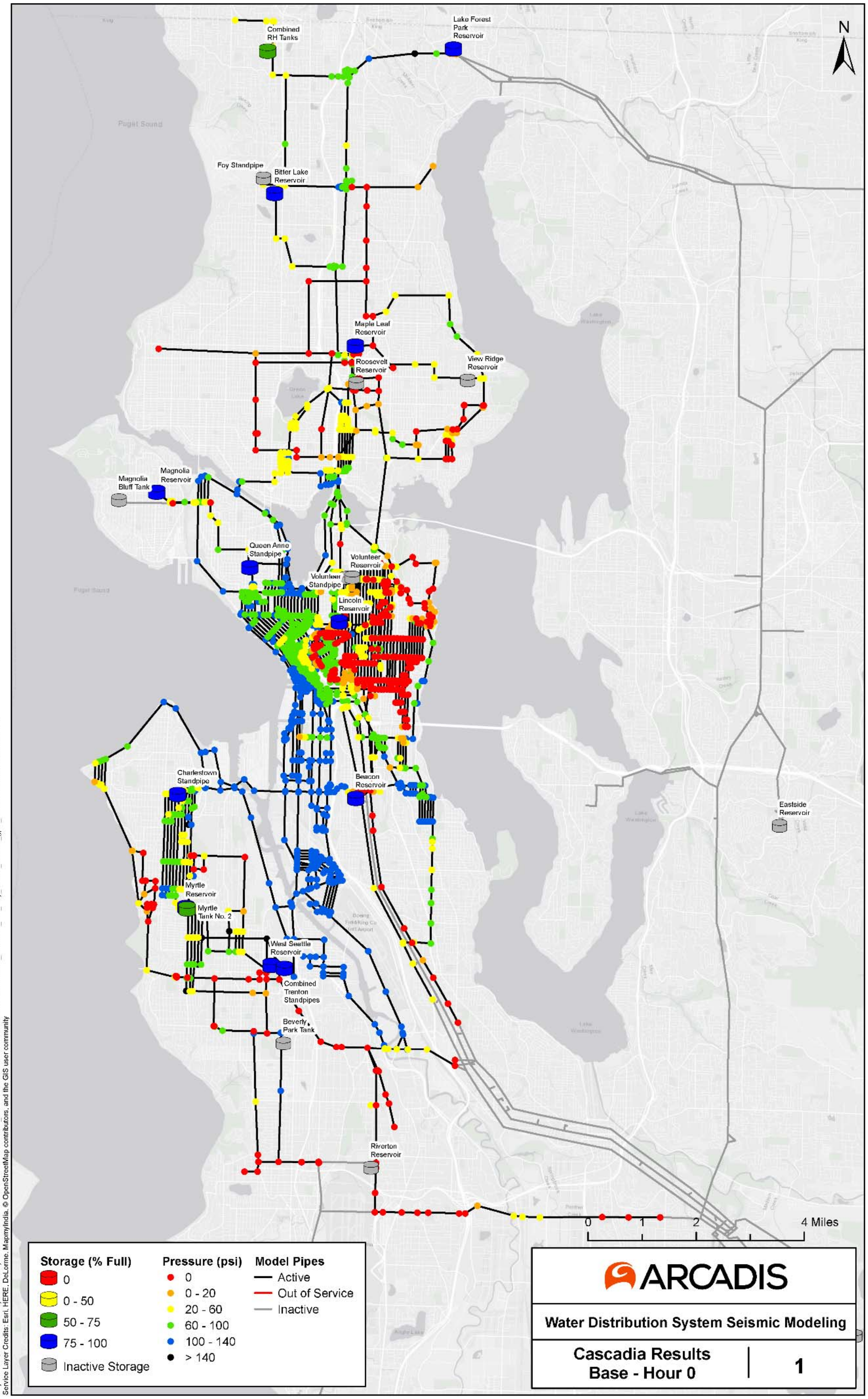

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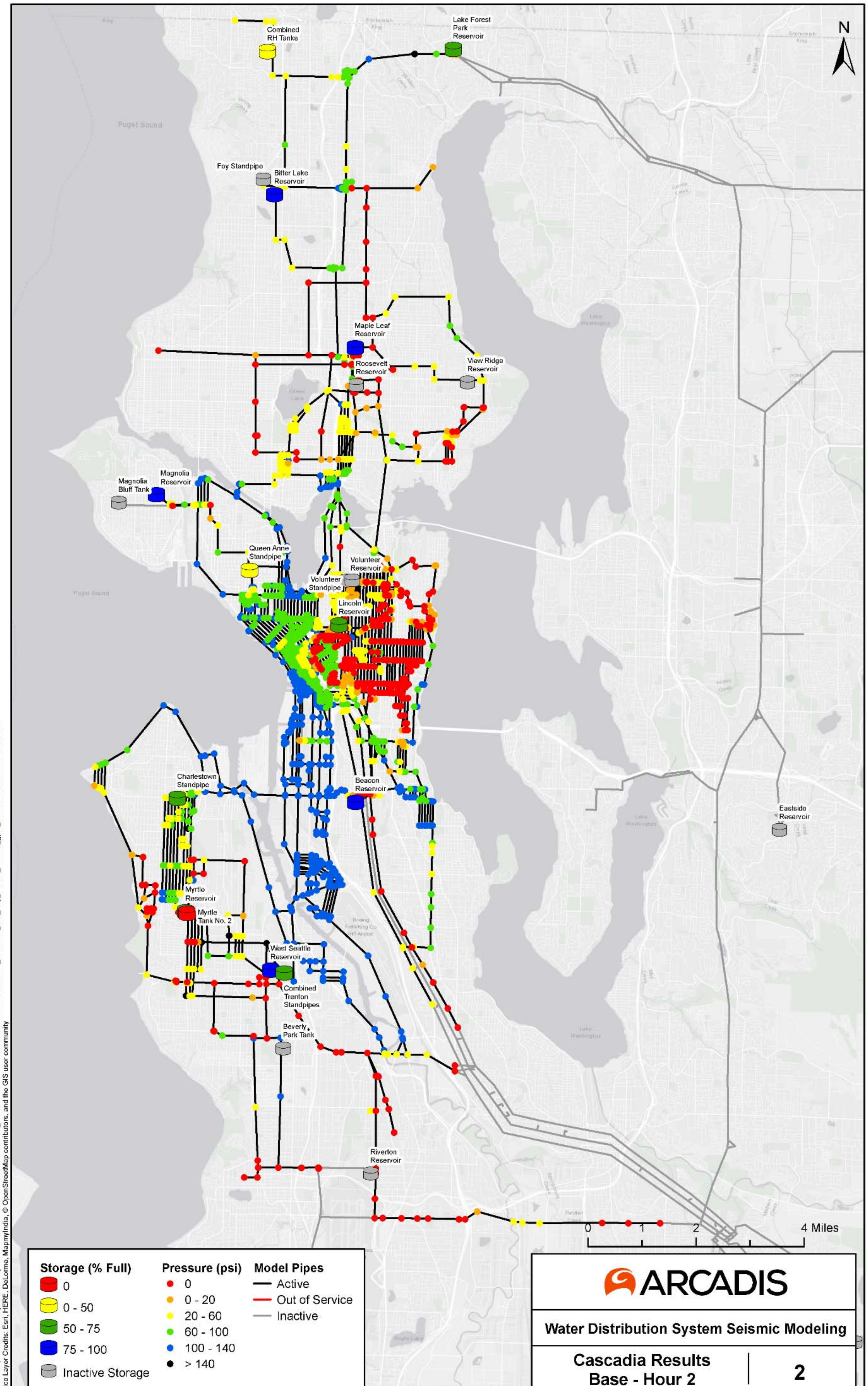

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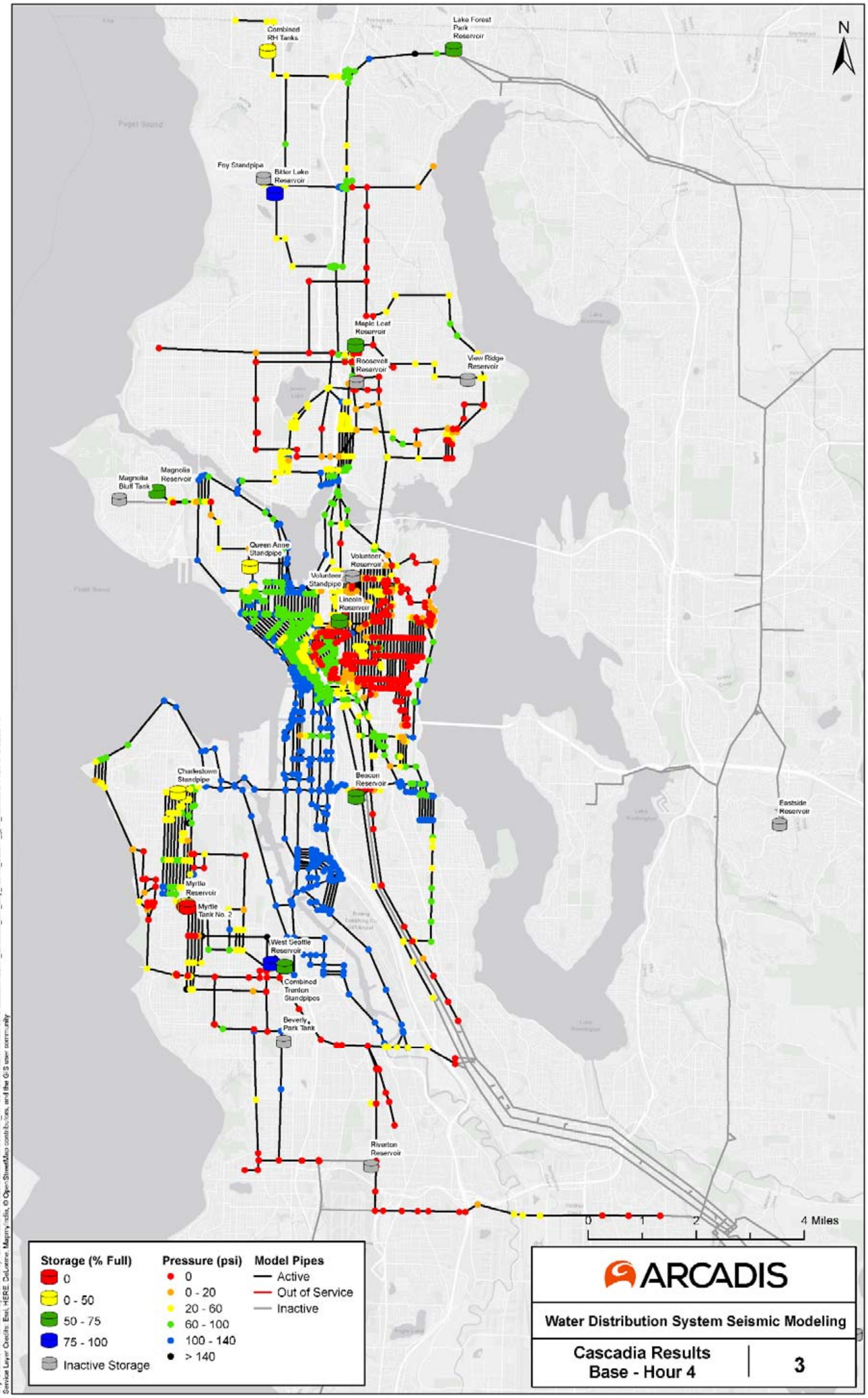

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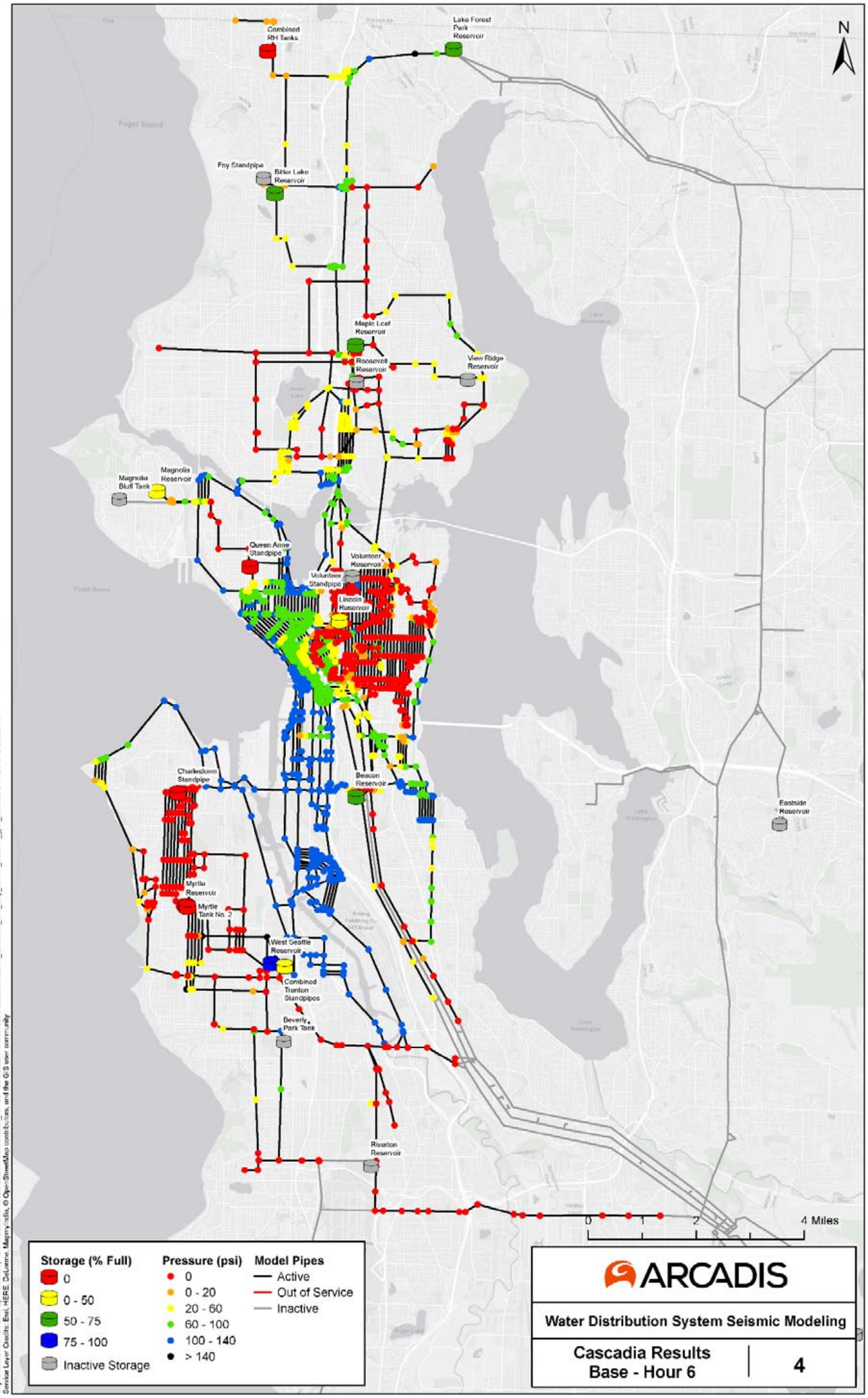

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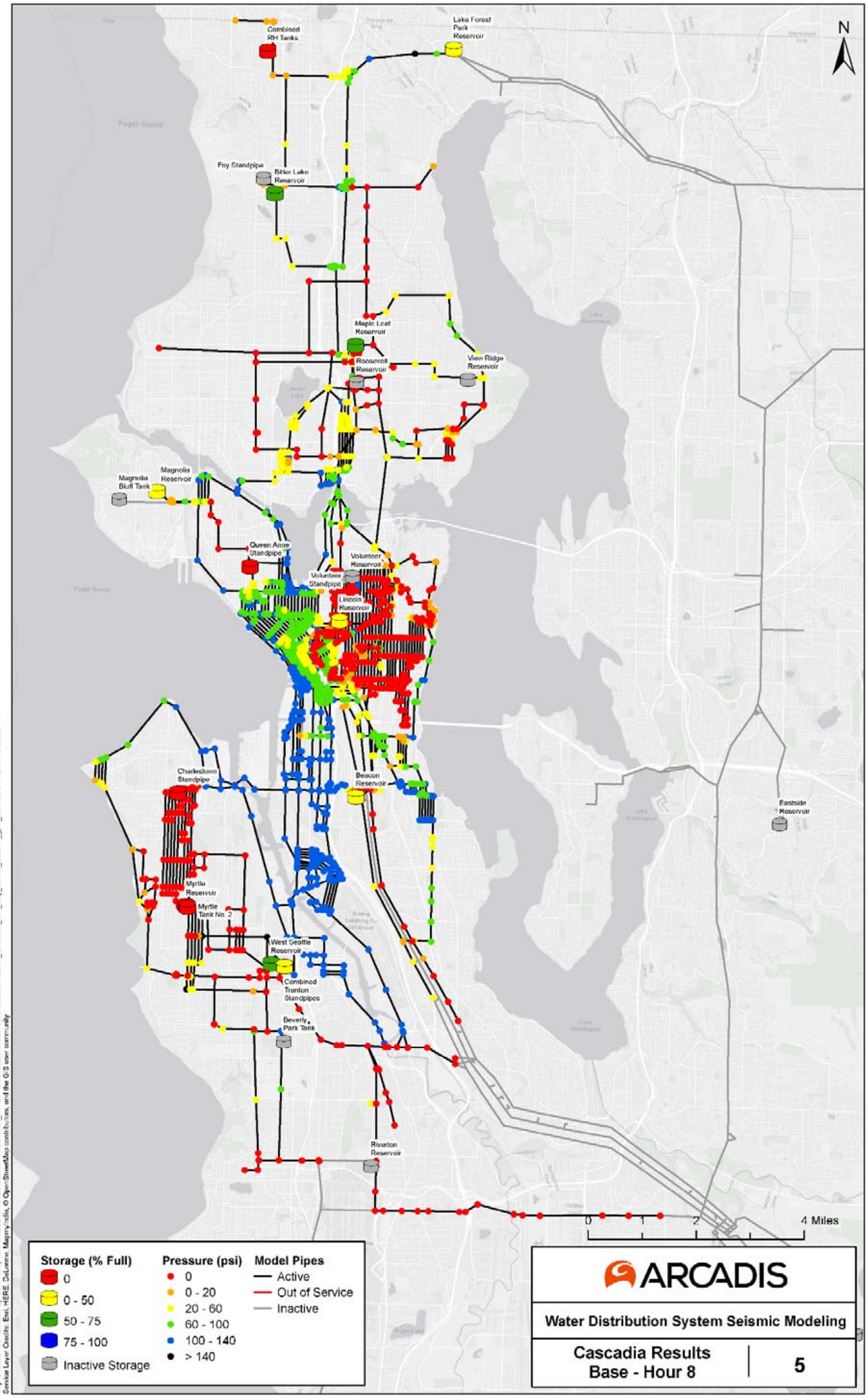
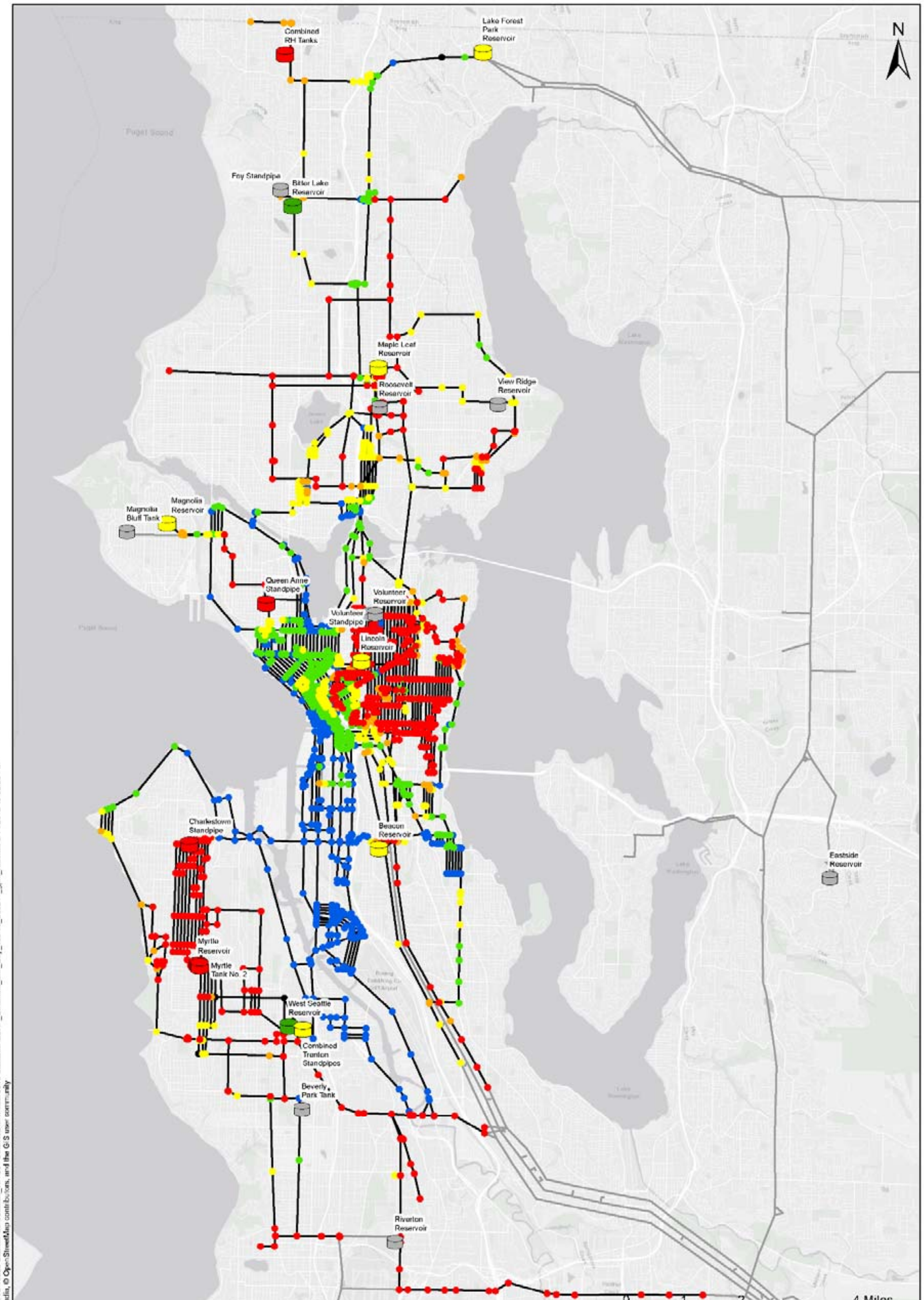


Combined RH Tanks
Lake Forest Park Reservoir
N
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
Cascadia Results
Base - Hour 8
5


N
Combined RH Tanks
Lake Forest Park Reservoir
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
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Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
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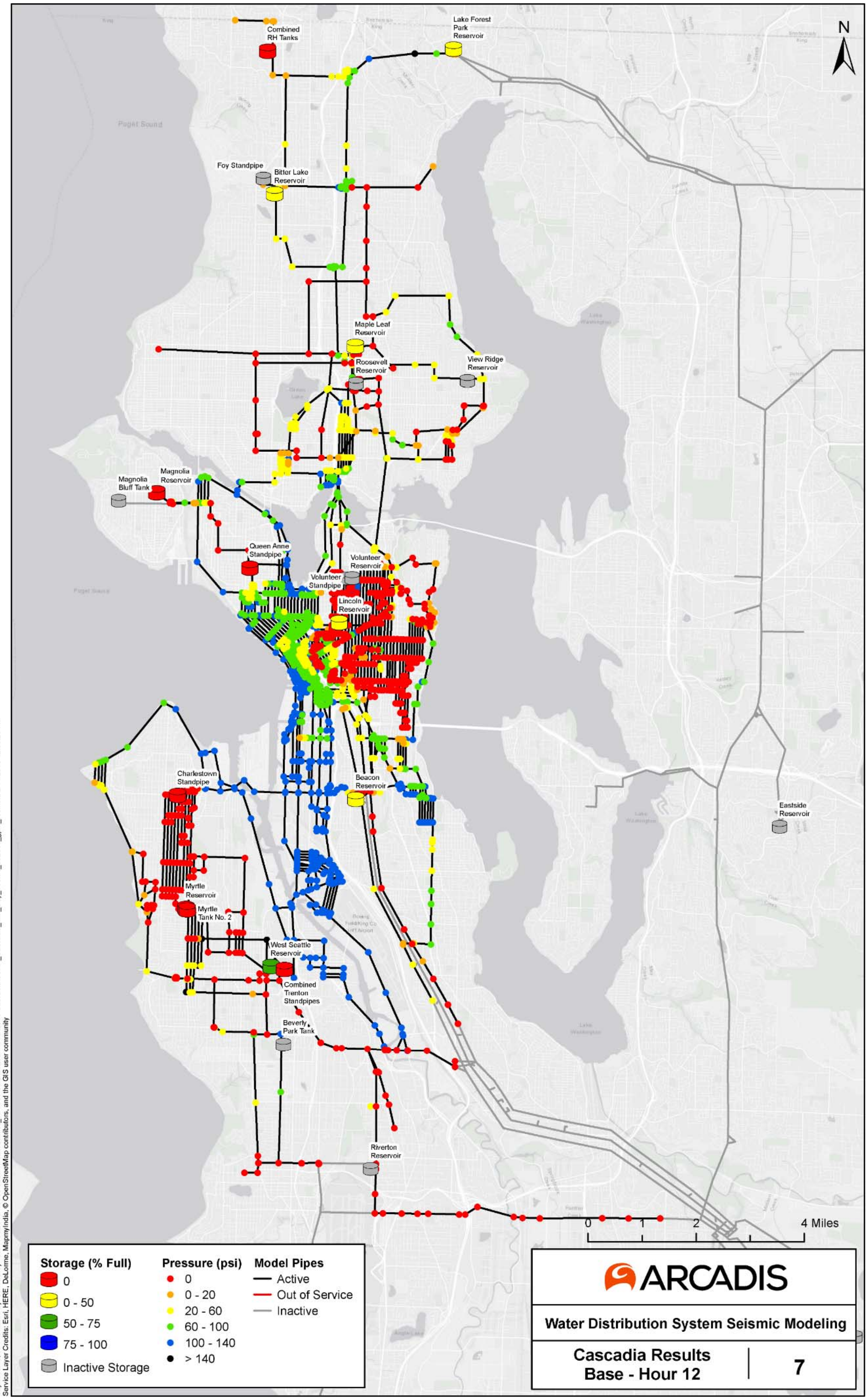
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
Cascadia Results
Base - Hour 10
6



Water Distribution System Seismic Modeling

Cascadia Results
Base - Hour 12

7

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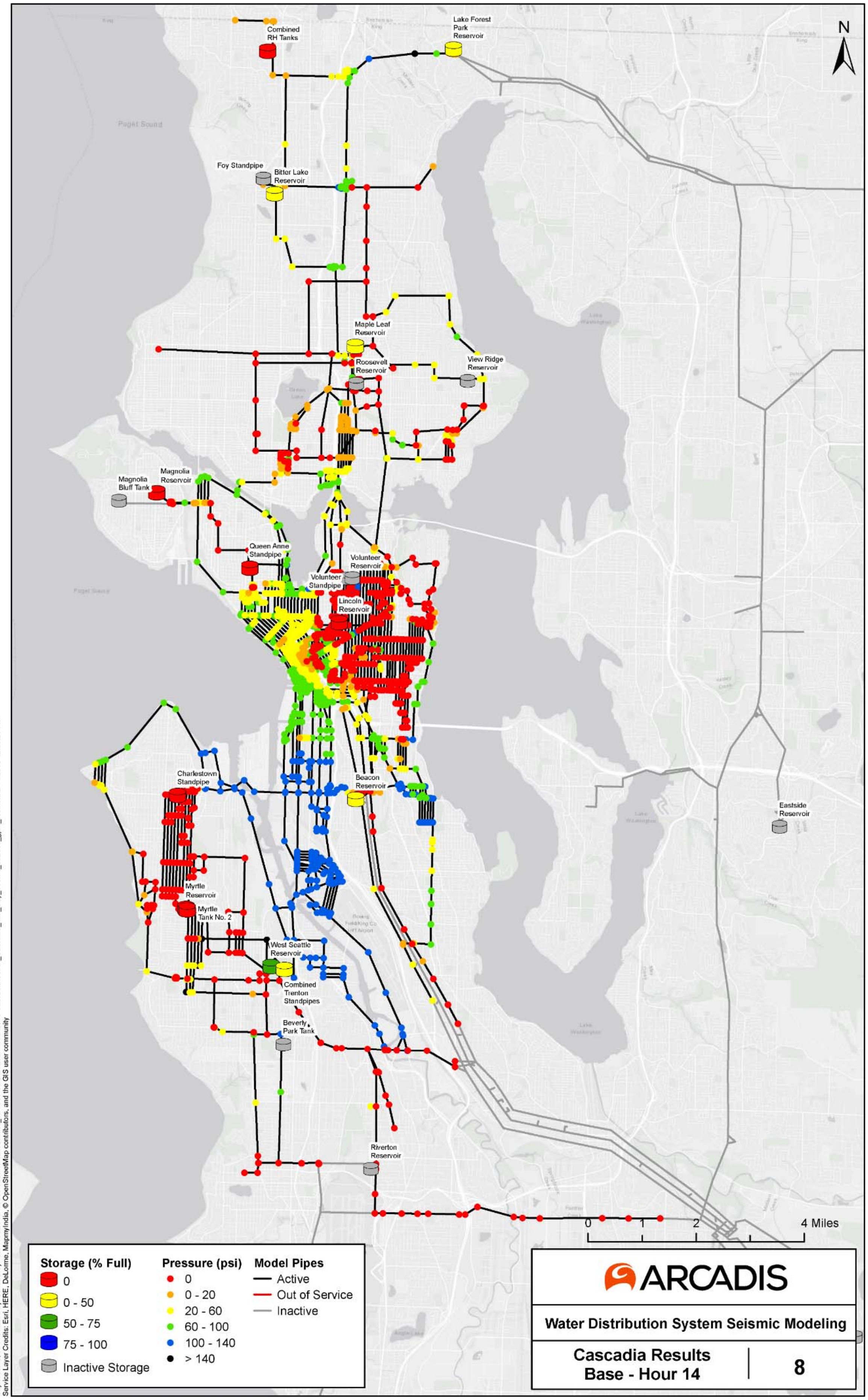

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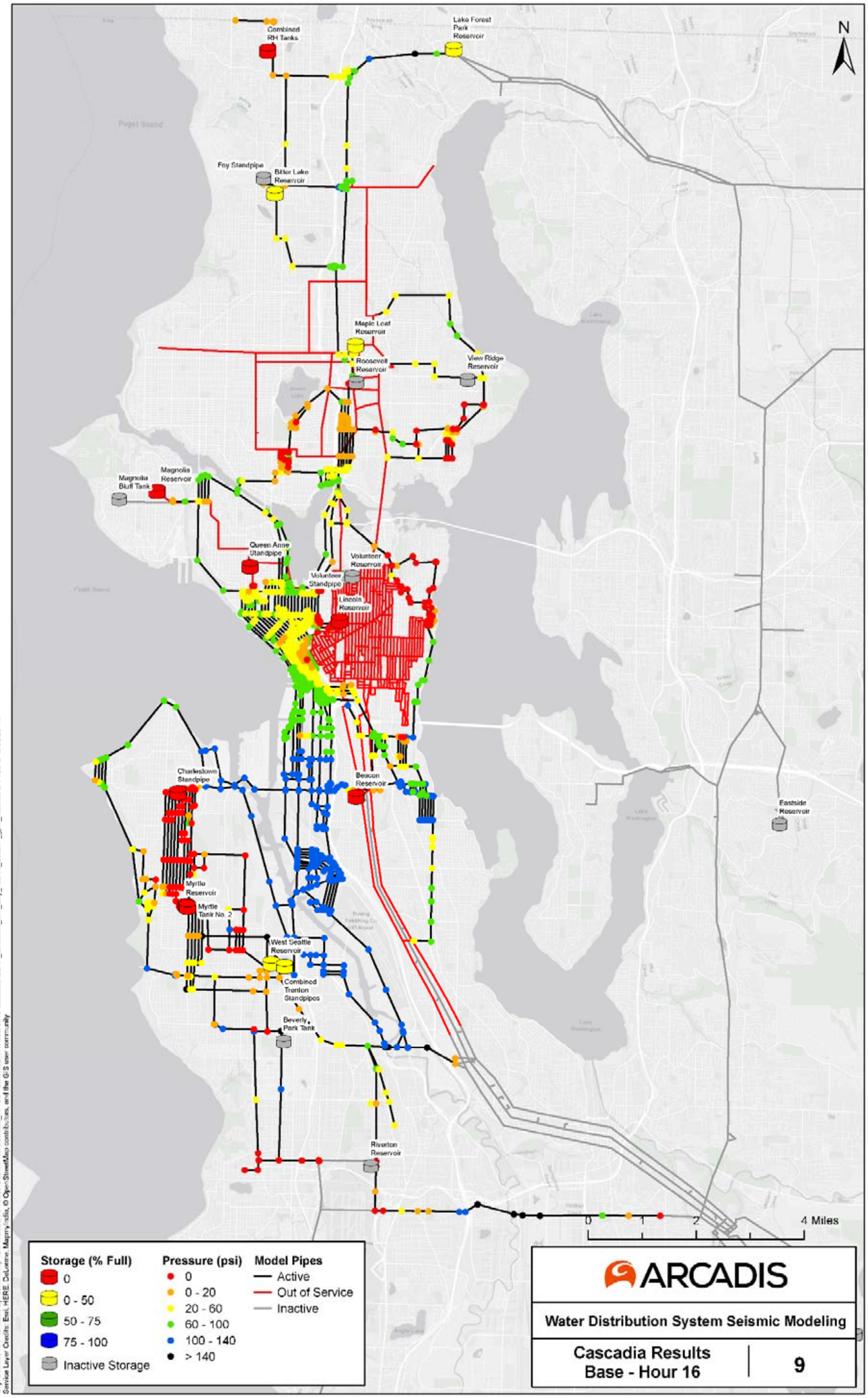

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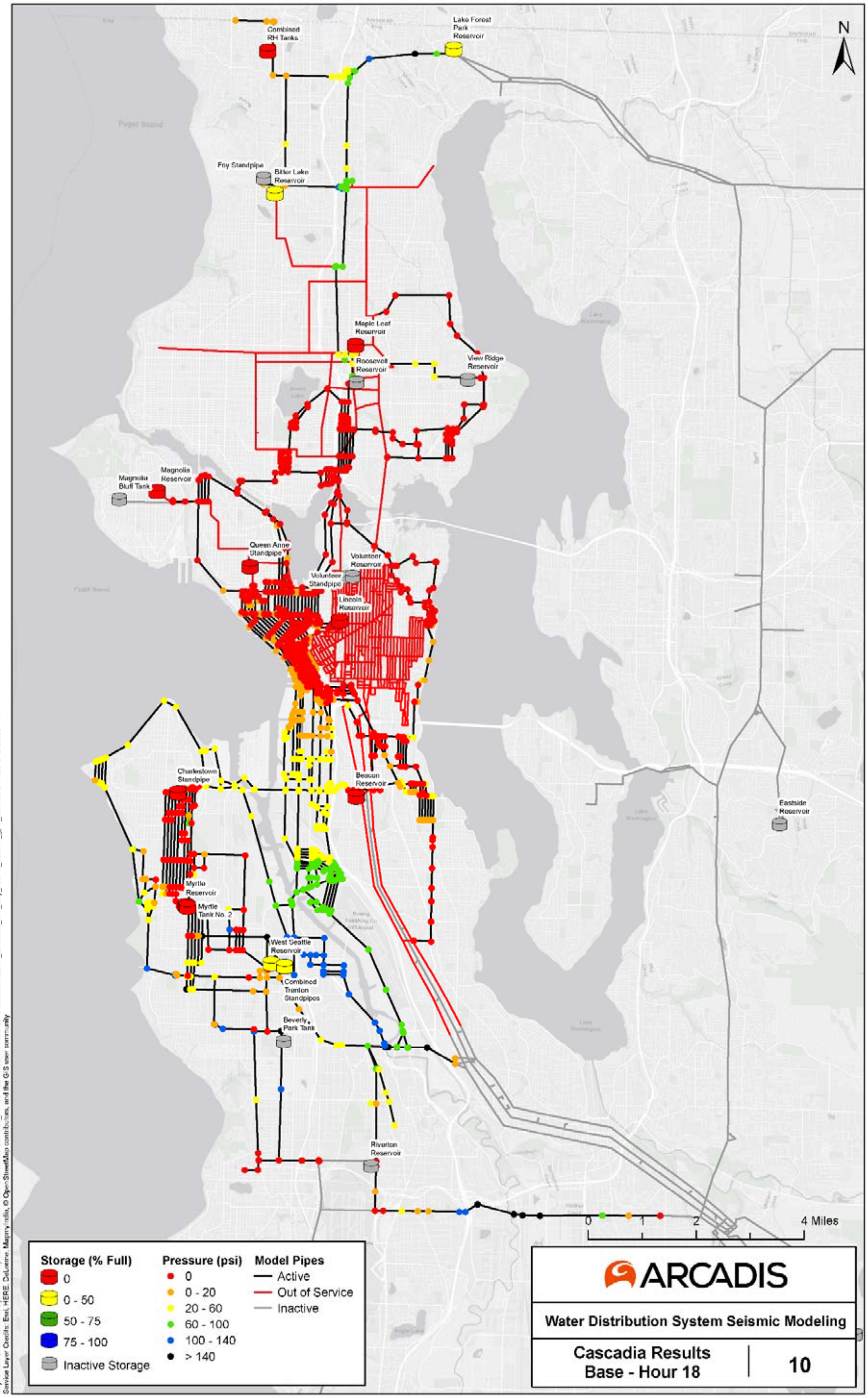

N
Combined RH Tanks
Lake Forest Park Reservoir
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
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0
1
2
4 Miles
Storage (% Full)
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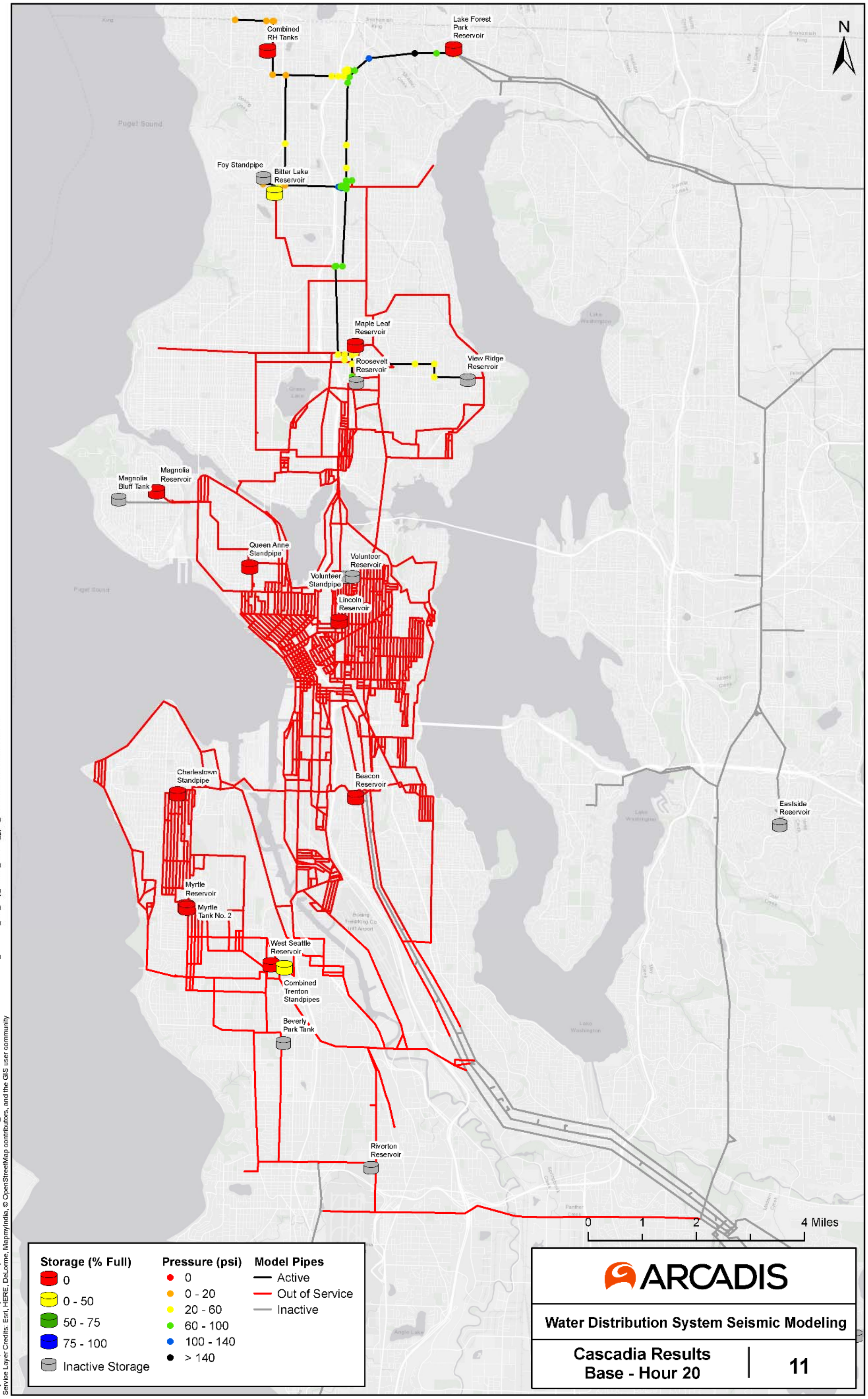
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
Cascadia Results
Base - Hour 18
10



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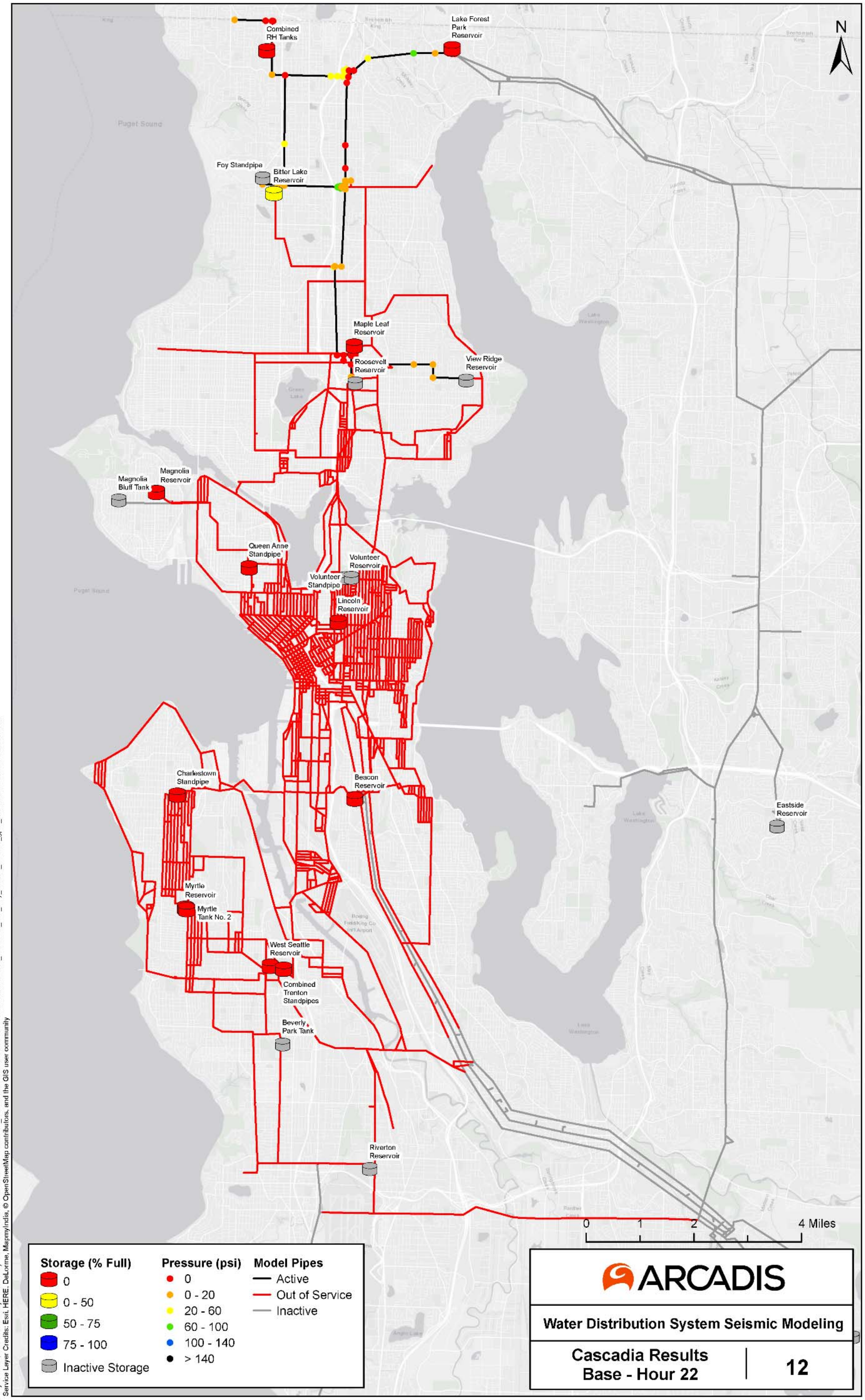

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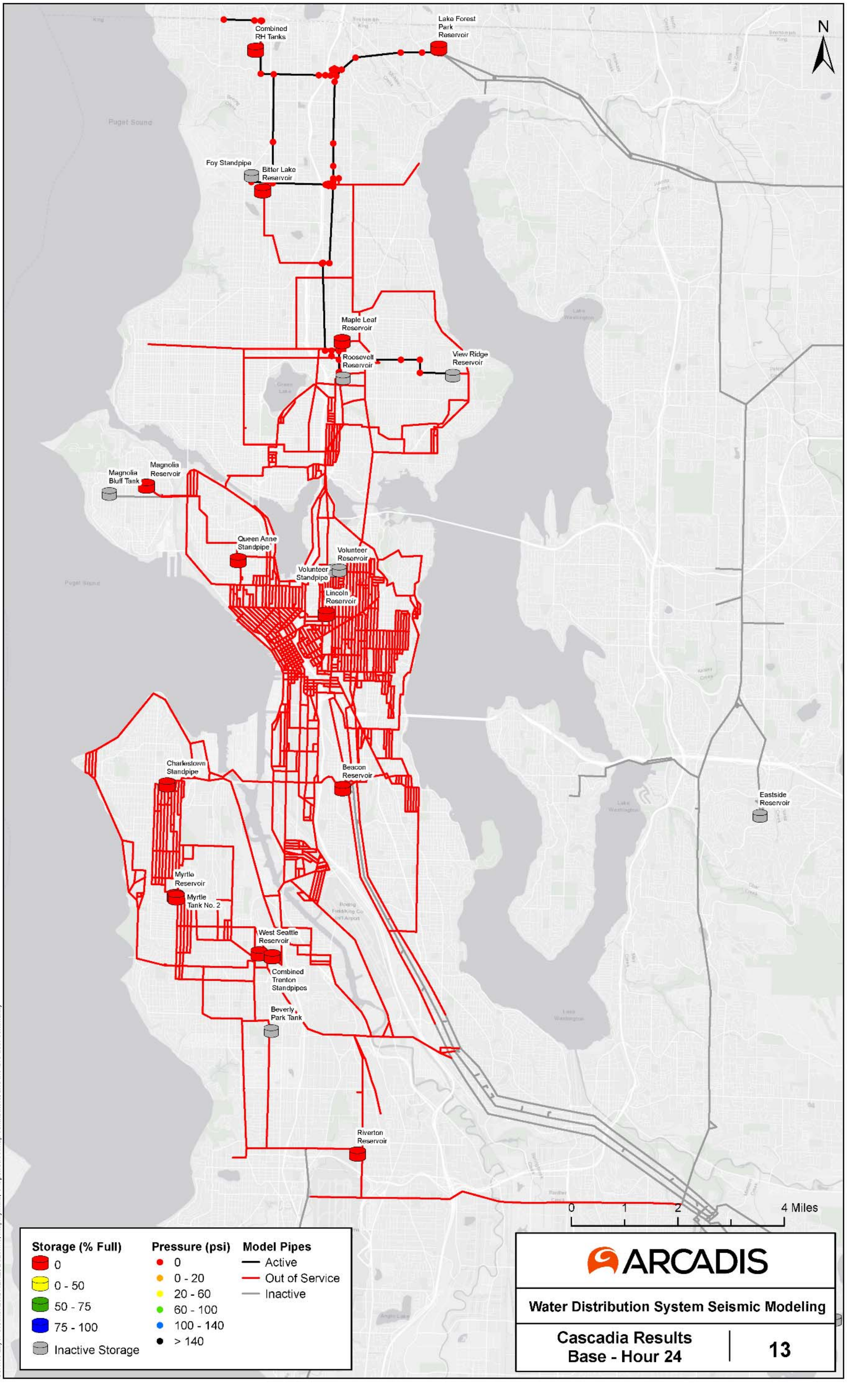

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M7.0 Seattle Fault Zone Case 1 (20 Year Improvements) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

1/26/2018

Seattle Fault Seismic Event

Case 1 Isolation and Control and Most-Critical Facility Upgrades

Some facilities shown below are now functional
Assume that certain emitters are now zero and
that certain areas are automatically isolated to
prevent leakage

In Service Storage	*In Service Facilities*
Eastside Reservoir	Lincoln PS
Magnolia Bluff Elevated Tank	Broadway PS
Magnolia Reservoir	Spokane Street PS
Riverton Heights Reservoir	West Seattle PS

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	139,011	112,189	26,823	80%	287.2
3	125,861	99,889	25,972	78%	264.3
12	114,374	89,685	24,689	73%	201.1
22	39,026	31,588	7,437	15%	140.0
32	38,730	31,292	7,437	15%	108.0
48	14,716	10,501	4,215	11%	66.8

Model Regions Forced Out of Service During Simulation

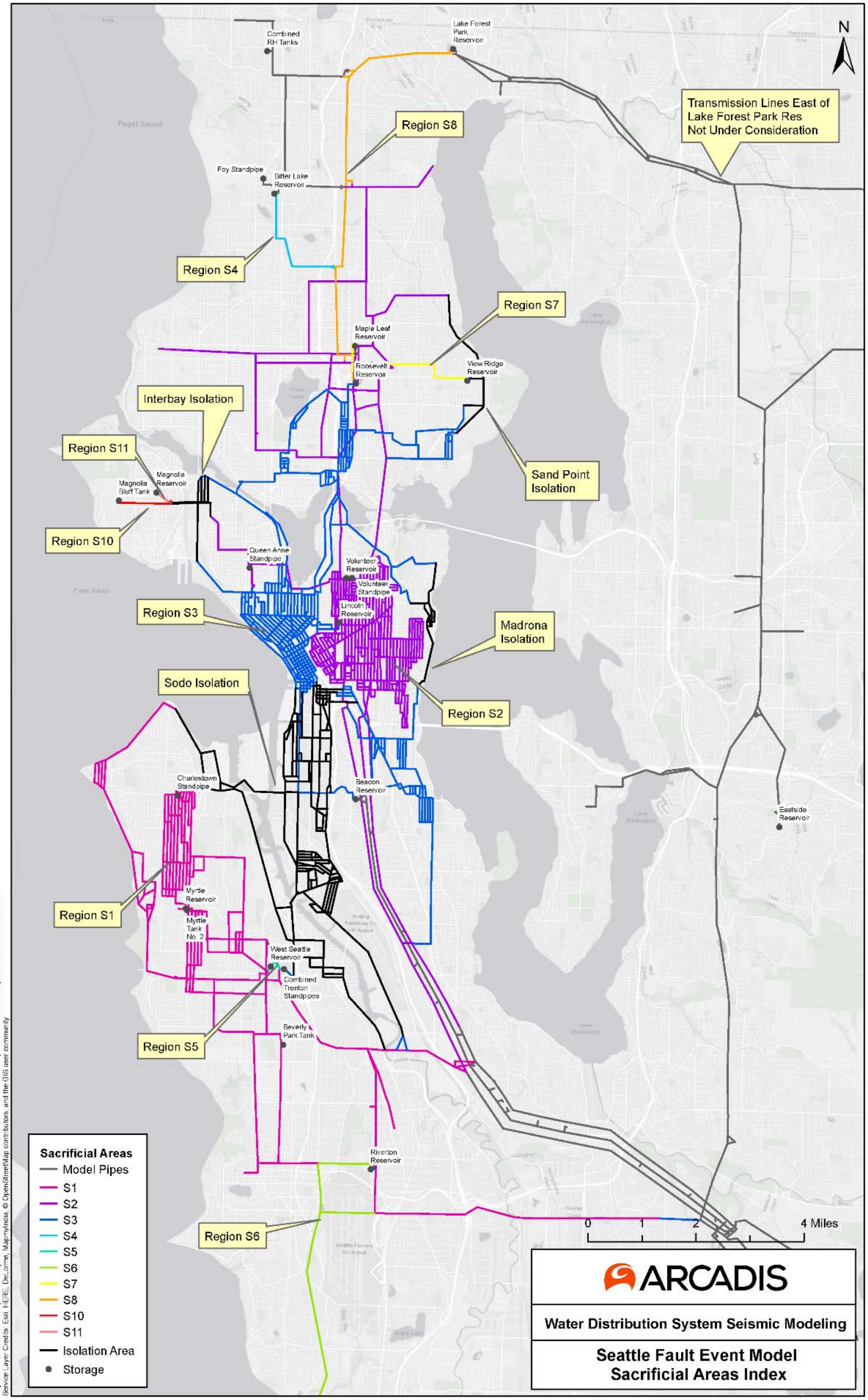
Time	Region
1	S10
16	S6
22	S2
45	S8
47	S4

Model Simulation Notes

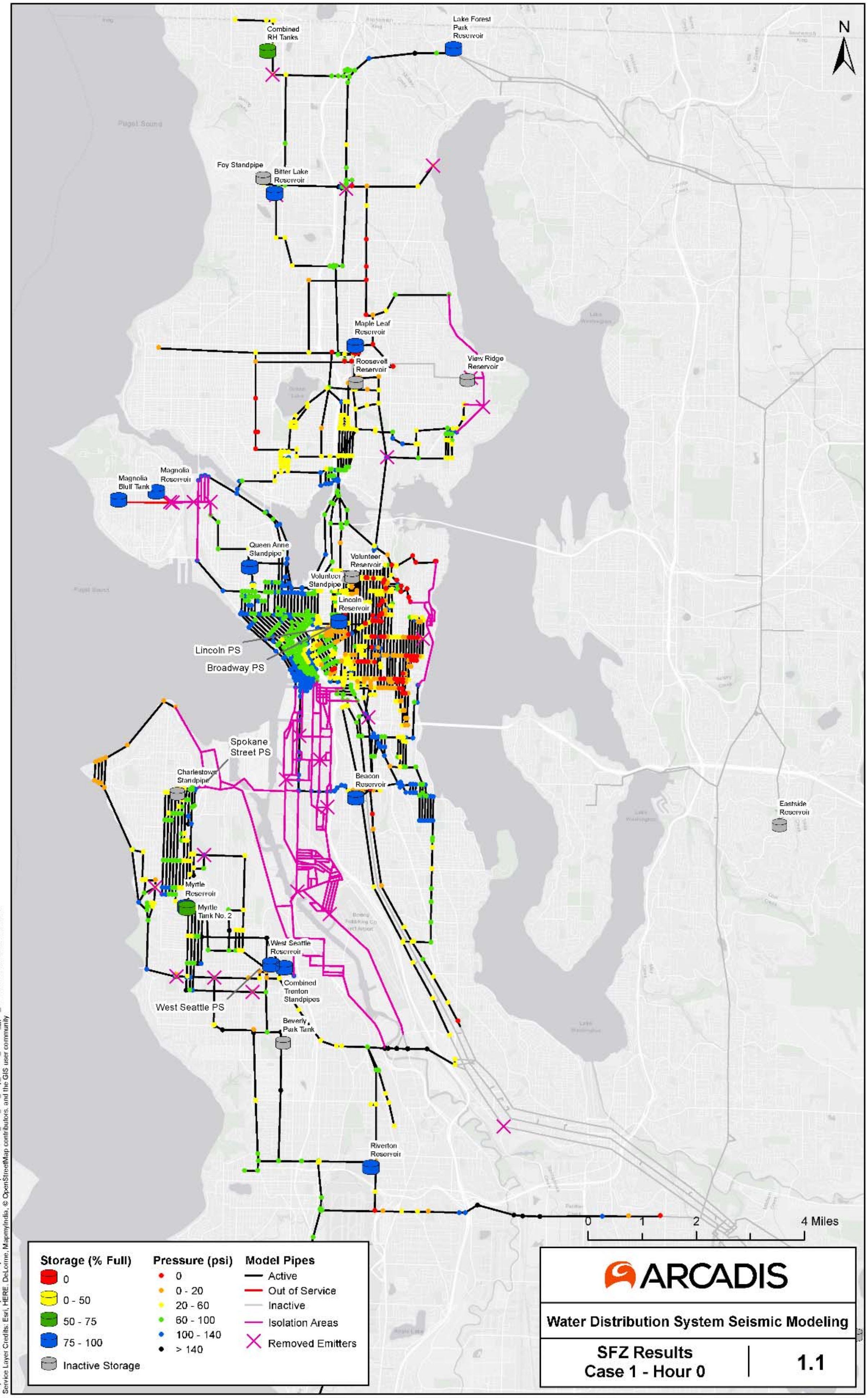
1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 1.1	Hr 0	Fig. 1.5	Hr 8	Fig. 1.9	Hr 16	Fig. 1.13	Hr 24	Fig. 1.17	Hr 40
Fig. 1.2	Hr 2	Fig. 1.6	Hr 10	Fig. 1.10	Hr 18	Fig. 1.14	Hr 28	Fig. 1.18	Hr 44
Fig. 1.3	Hr 4	Fig. 1.7	Hr 12	Fig. 1.11	Hr 20	Fig. 1.15	Hr 32	Fig. 1.19	Hr 48



Combined RH Tanks
Lake Forest Park Reservoir
N
Transmission Lines East of Lake Forest Park Res Not Under Consideration
Region S8
Foy Standpipe
Bitter Lake Reservoir
Region S4
Region S7
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Interbay Isolation
Region S11
Magnolia Reservoir
Magnolia Bluff Tank
Region S10
Sand Point Isolation
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Region S3
Madrona Isolation
Sodo Isolation
Region S2
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Region S1
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Region S5
Beverly Park Tank
Riverton Reservoir
Region S6
0
1
2
4 Miles
Sacrificial Areas
Model Pipes
S1
S2
S3
S4
S5
S6
S7
S8
S10
S11
Isolation Area
Storage
ARCADIS
Water Distribution System Seismic Modeling
Seattle Fault Event Model
Sacrificial Areas Index



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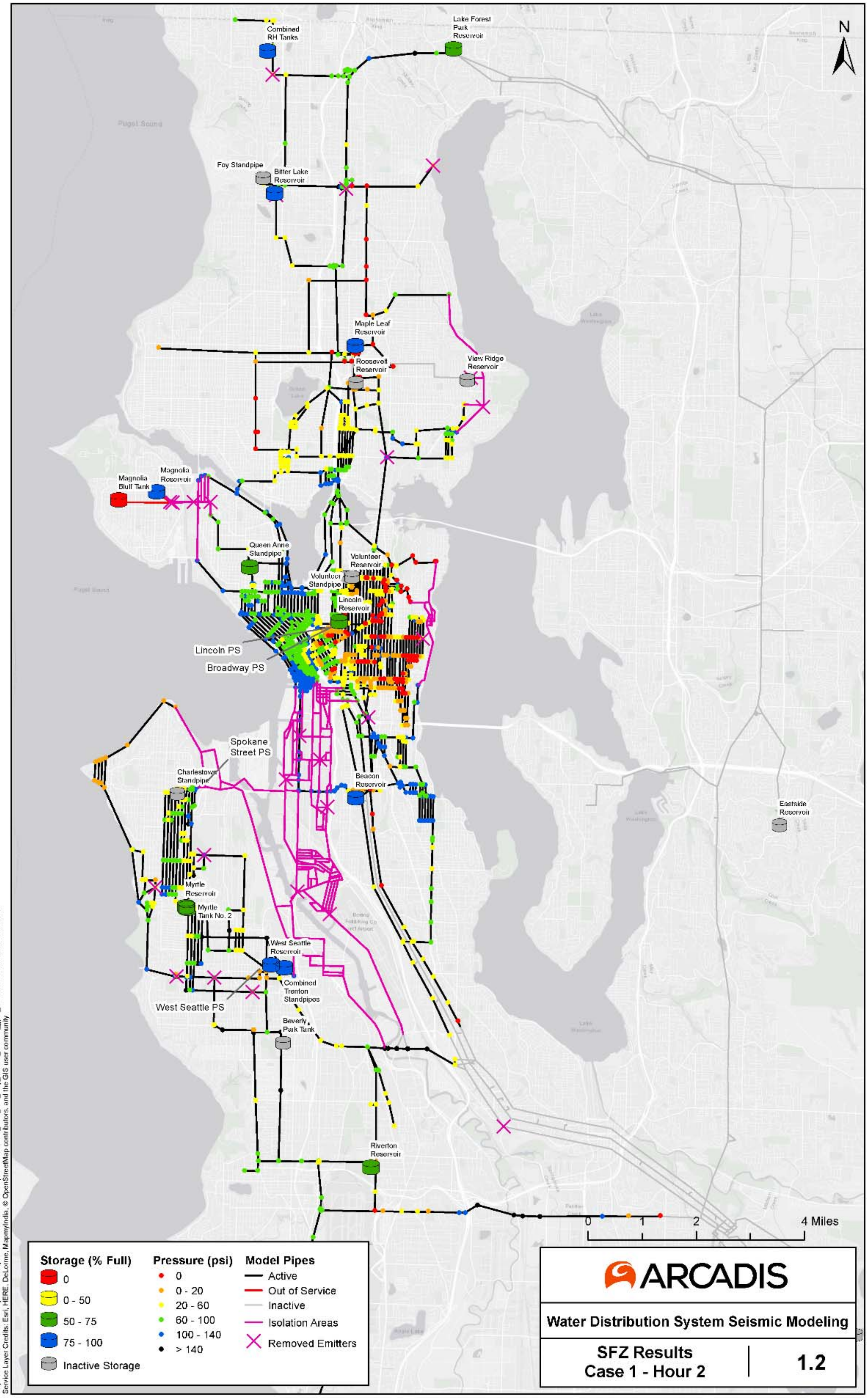
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



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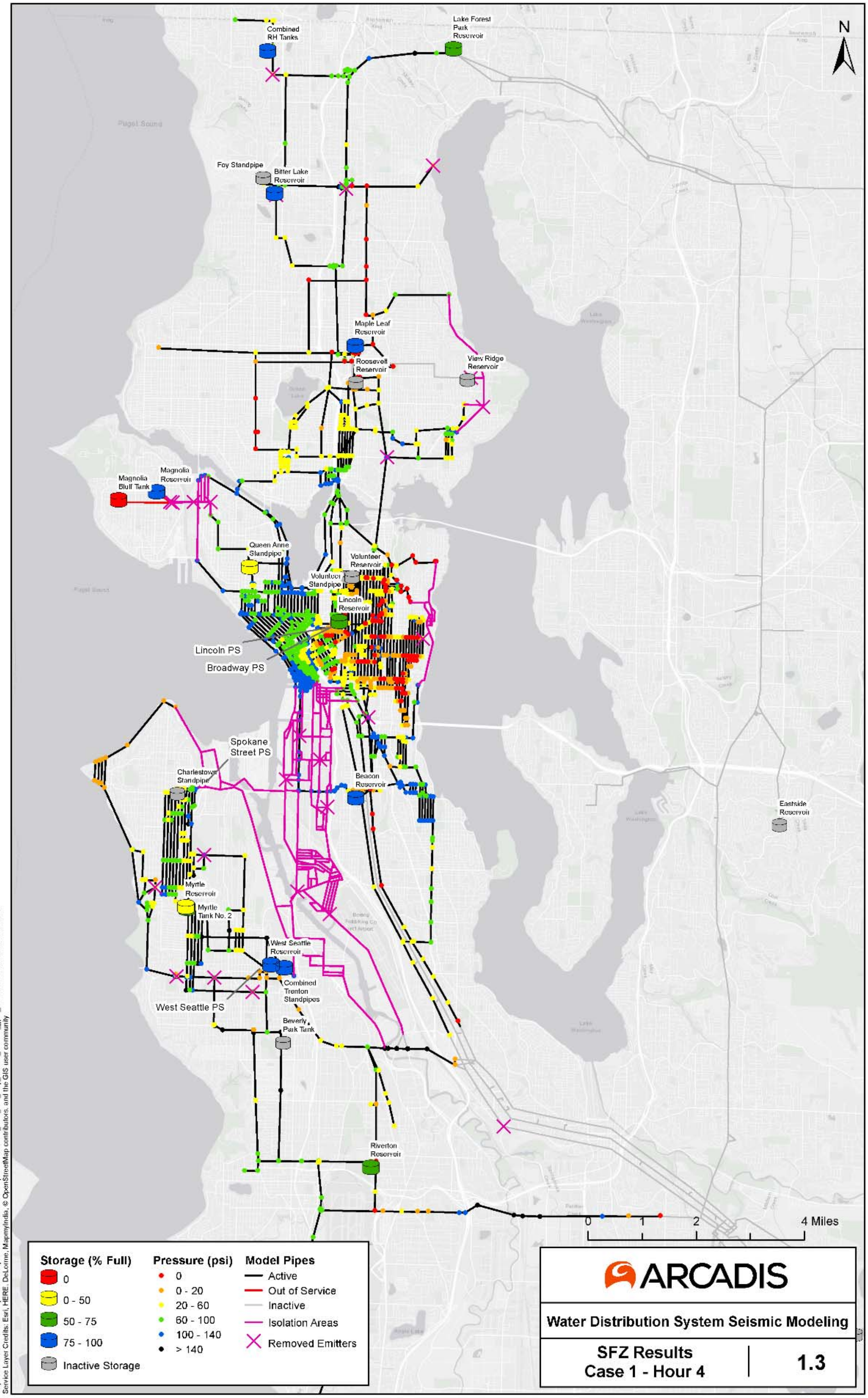

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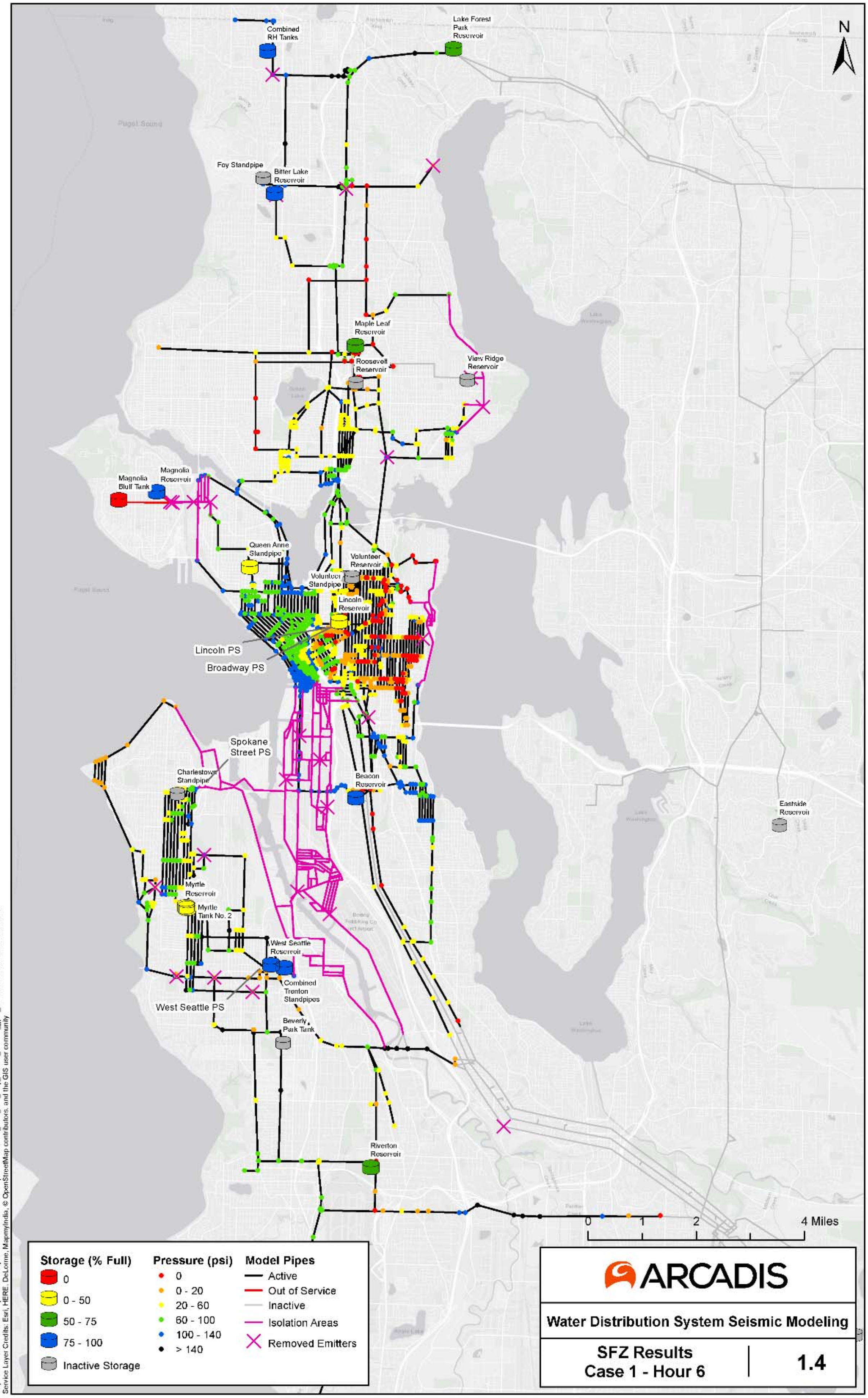

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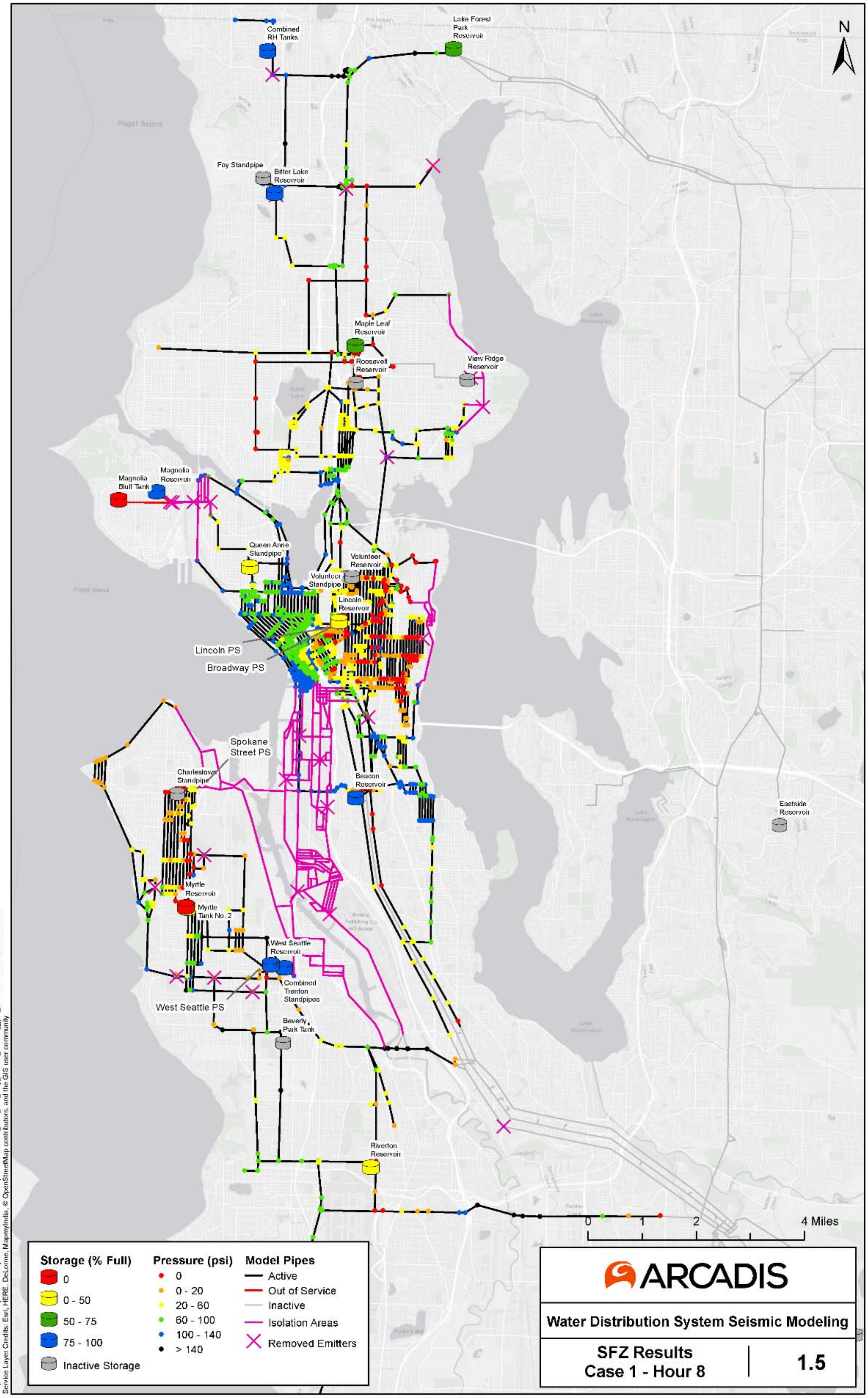

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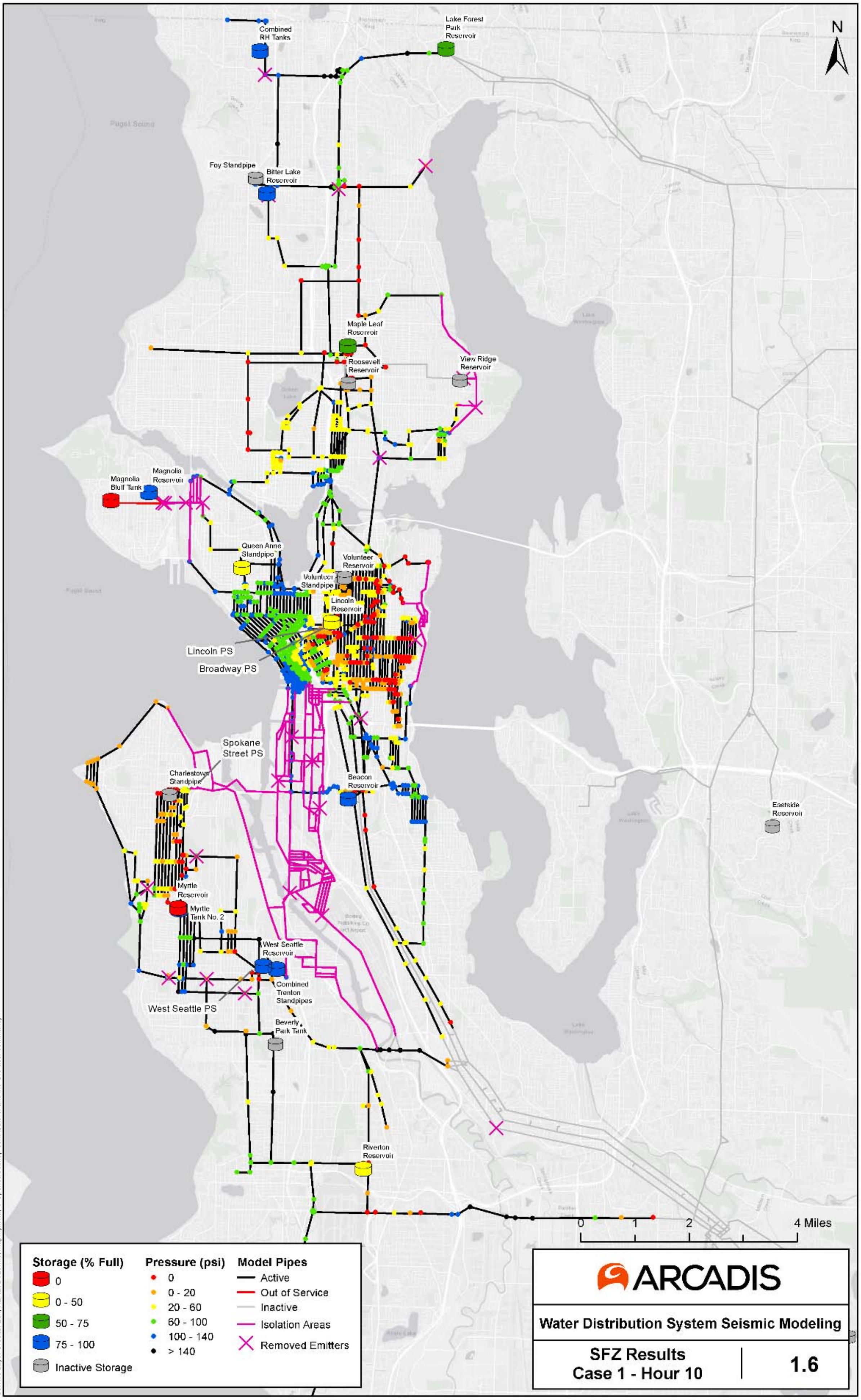

ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 1 - Hour 10

1.6

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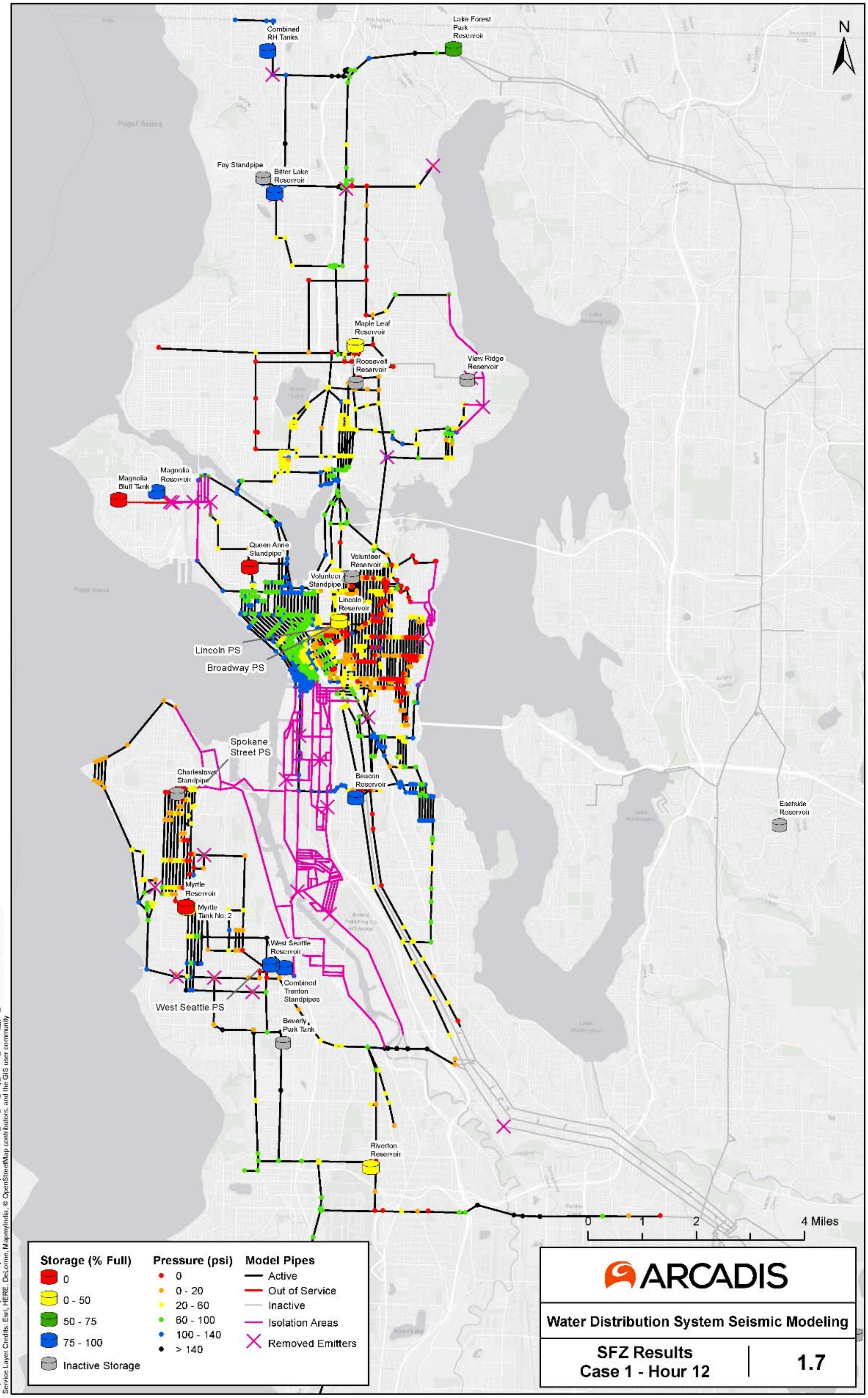
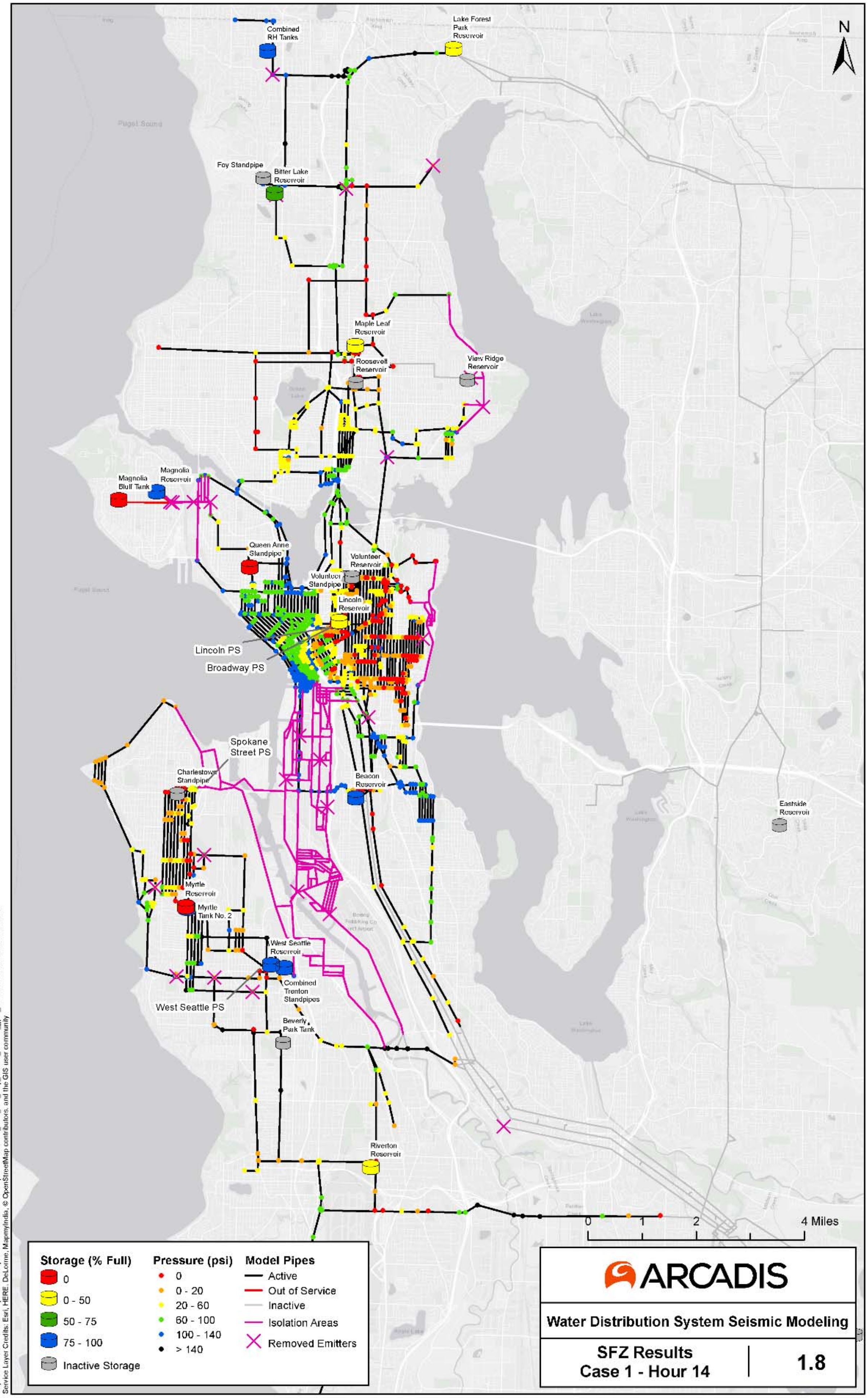

Combined
RH Tanks
Lake Forest
Park
Reservoir
N
Puget Sound
Foy Standpipe
Bitter Lake
Reservoir
Maple Leaf
Reservoir
Roosevelt
Reservoir
View Ridge
Reservoir
Magnolia
Bluff Tank
Magnolia
Reservoir
Queen Anne
Standpipe
Volunteer
Reservoir
Volunteer
Standpipe
Lincoln
Reservoir
Lincoln PS
Broadway PS
Spokane
Street PS
Charlestown
Standpipe
Beacon
Reservoir
Eastside
Reservoir
Myrtle
Reservoir
Myrtle
Tank No. 2
West Seattle
Reservoir
Combined
Trenton
Standpipes
West Seattle PS
Beverly
Park Tank
Riverton
Reservoir
0
1
2
4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
Removed Emitters
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 1 - Hour 12
1.7



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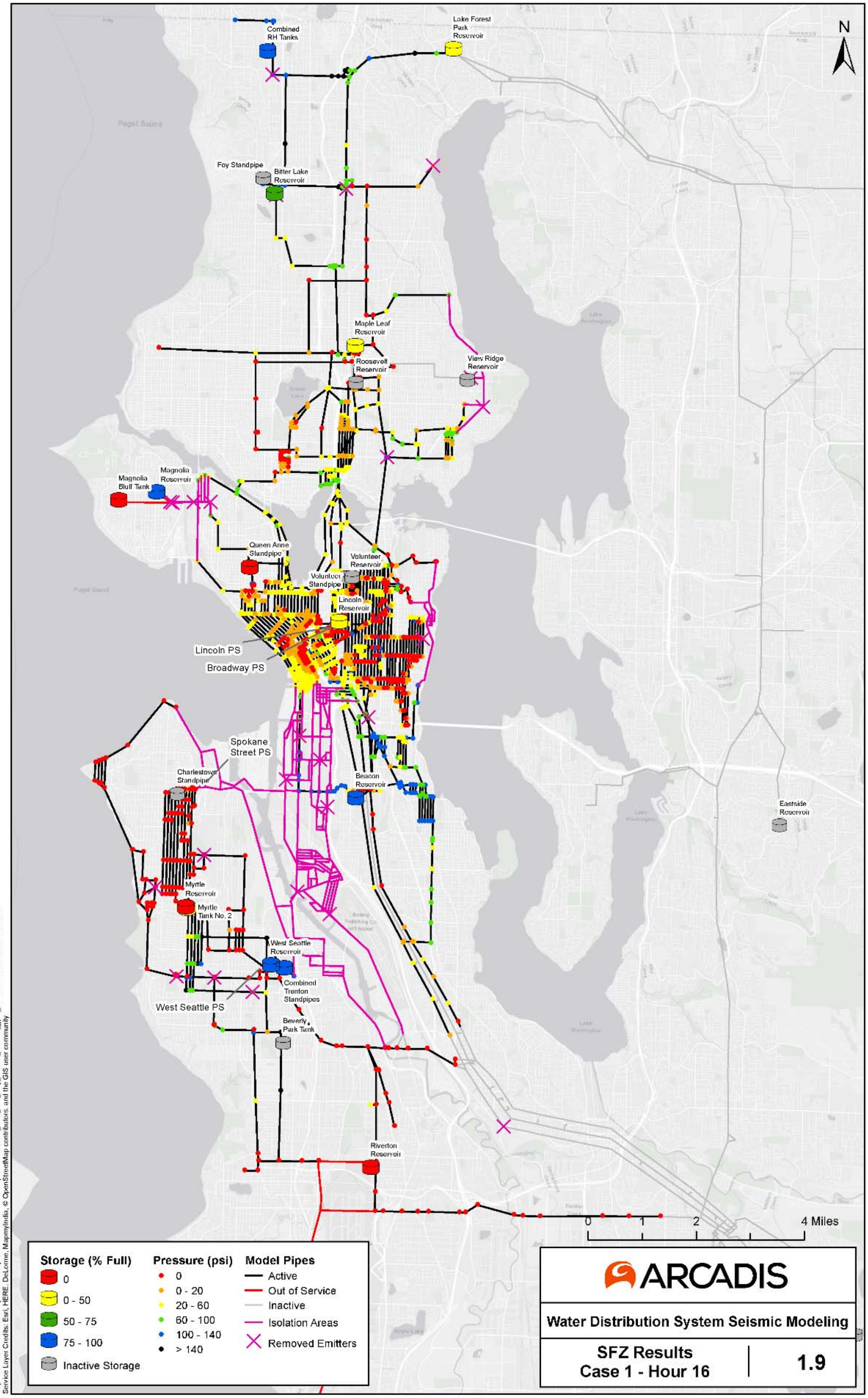

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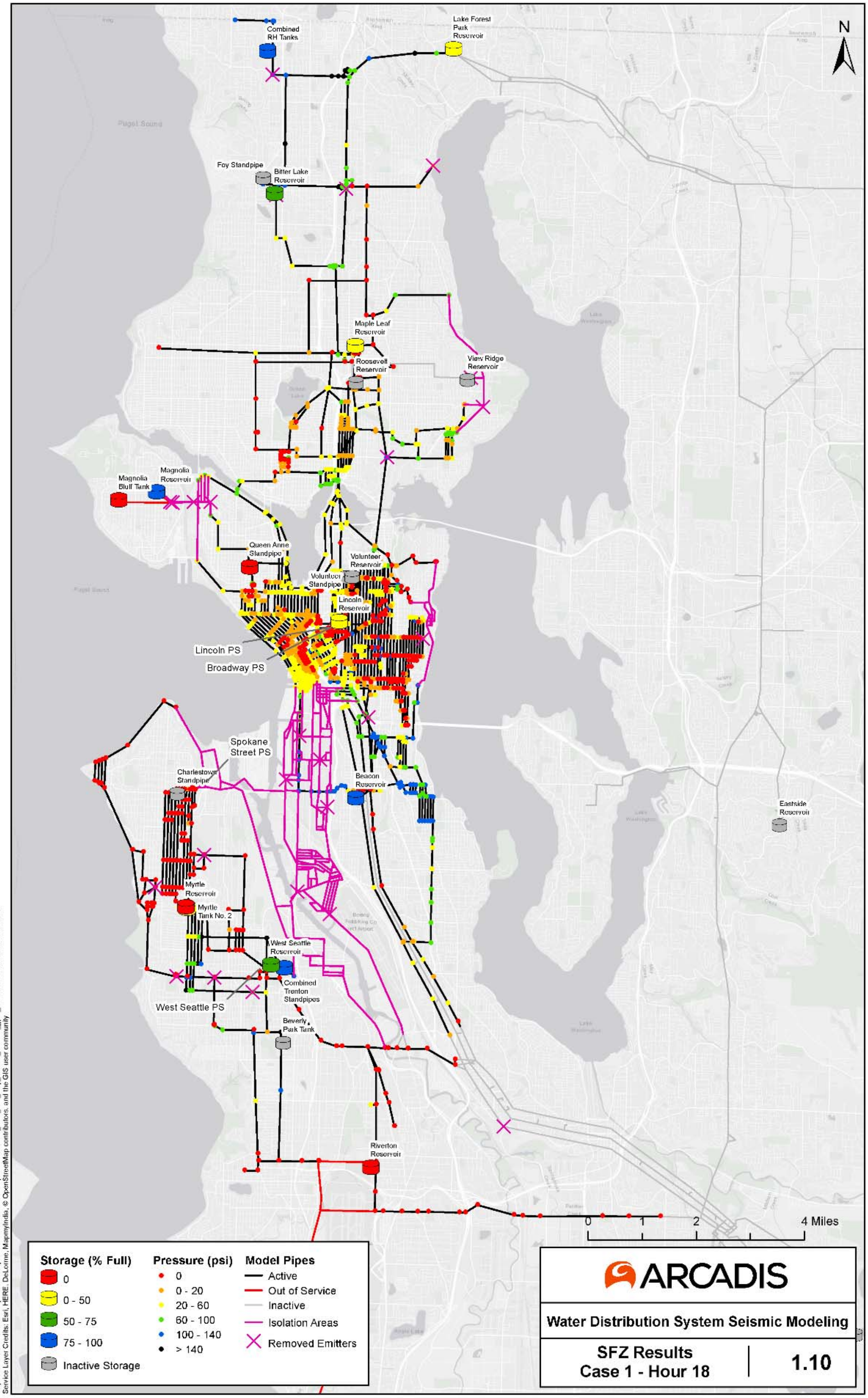

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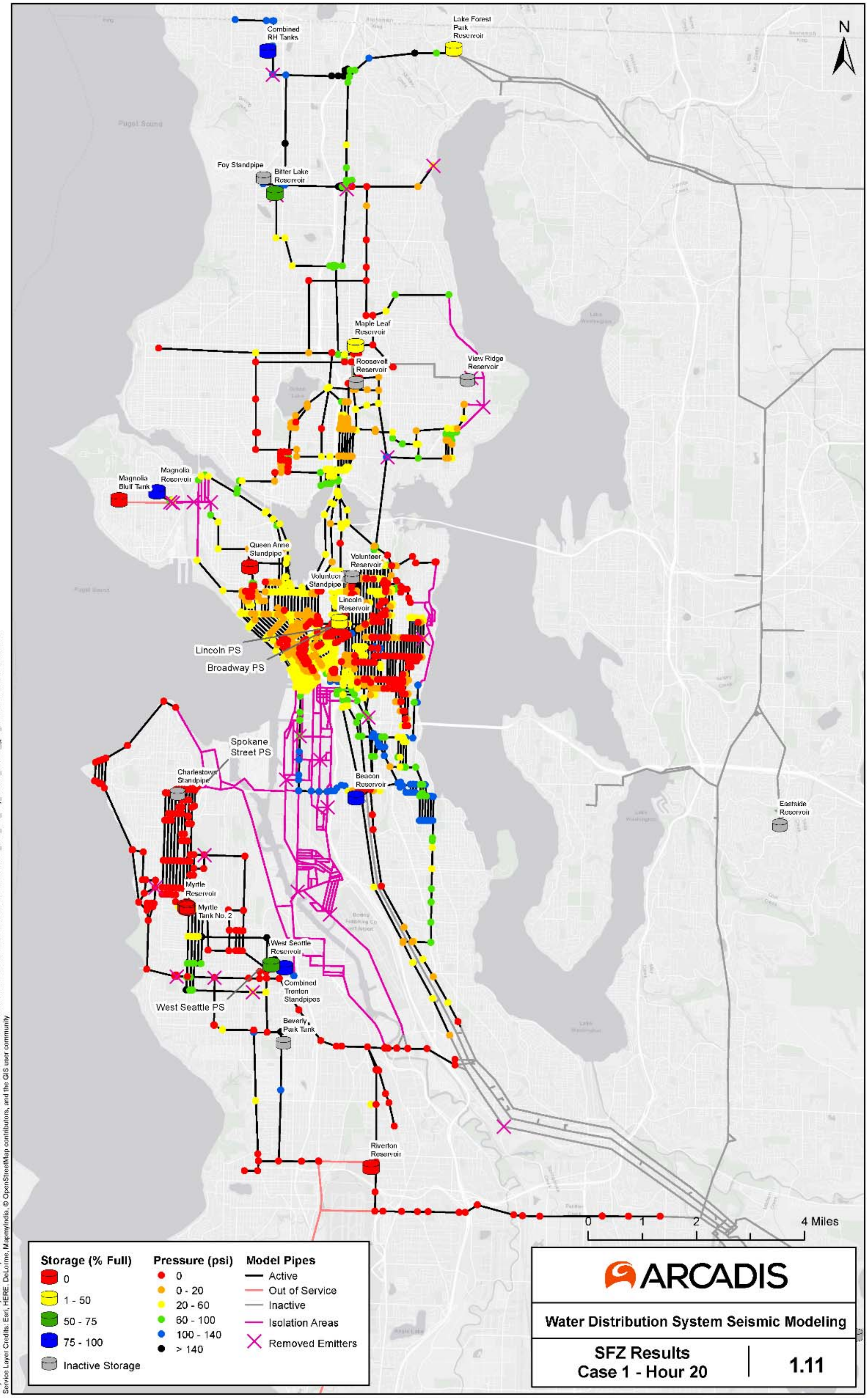

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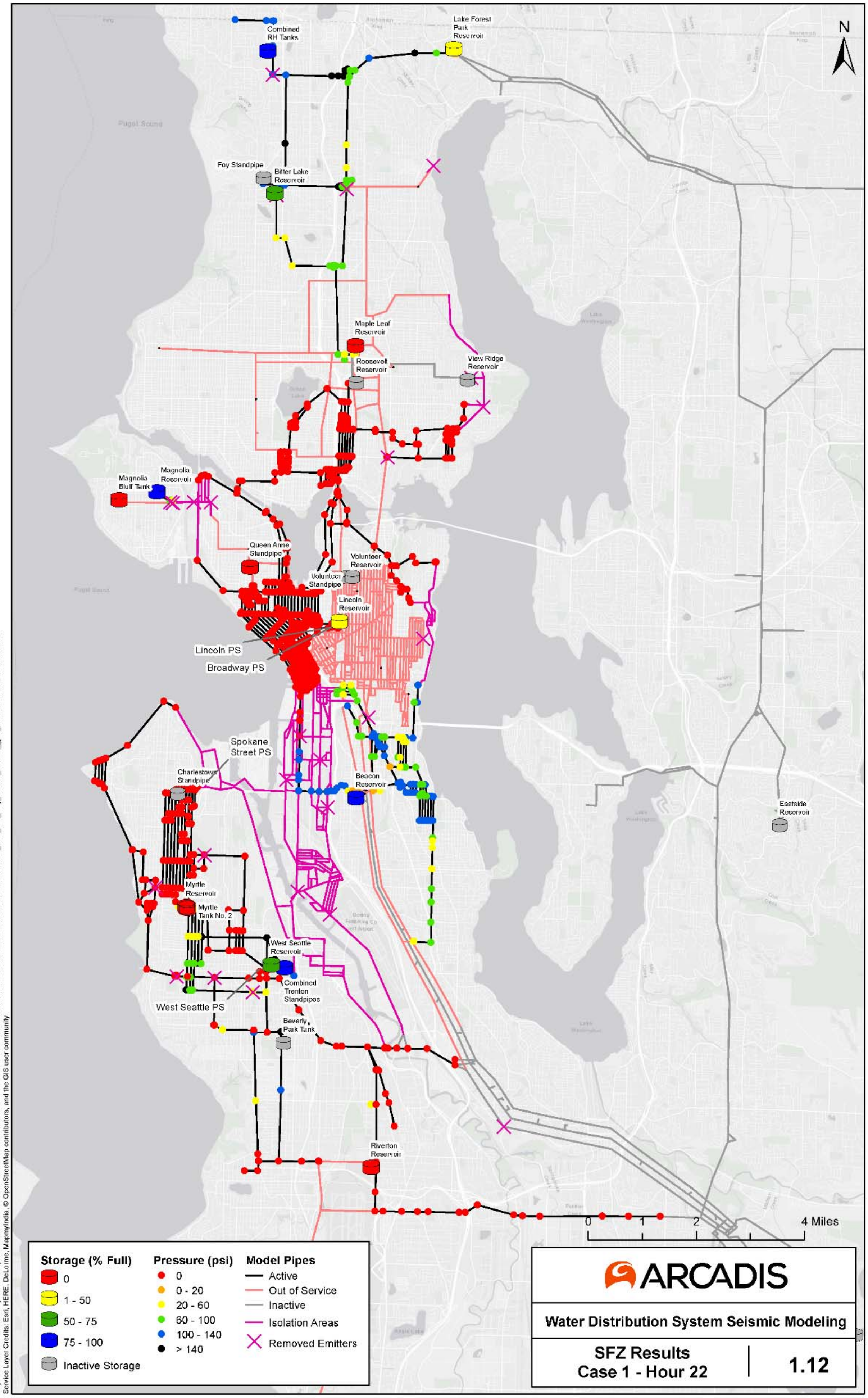

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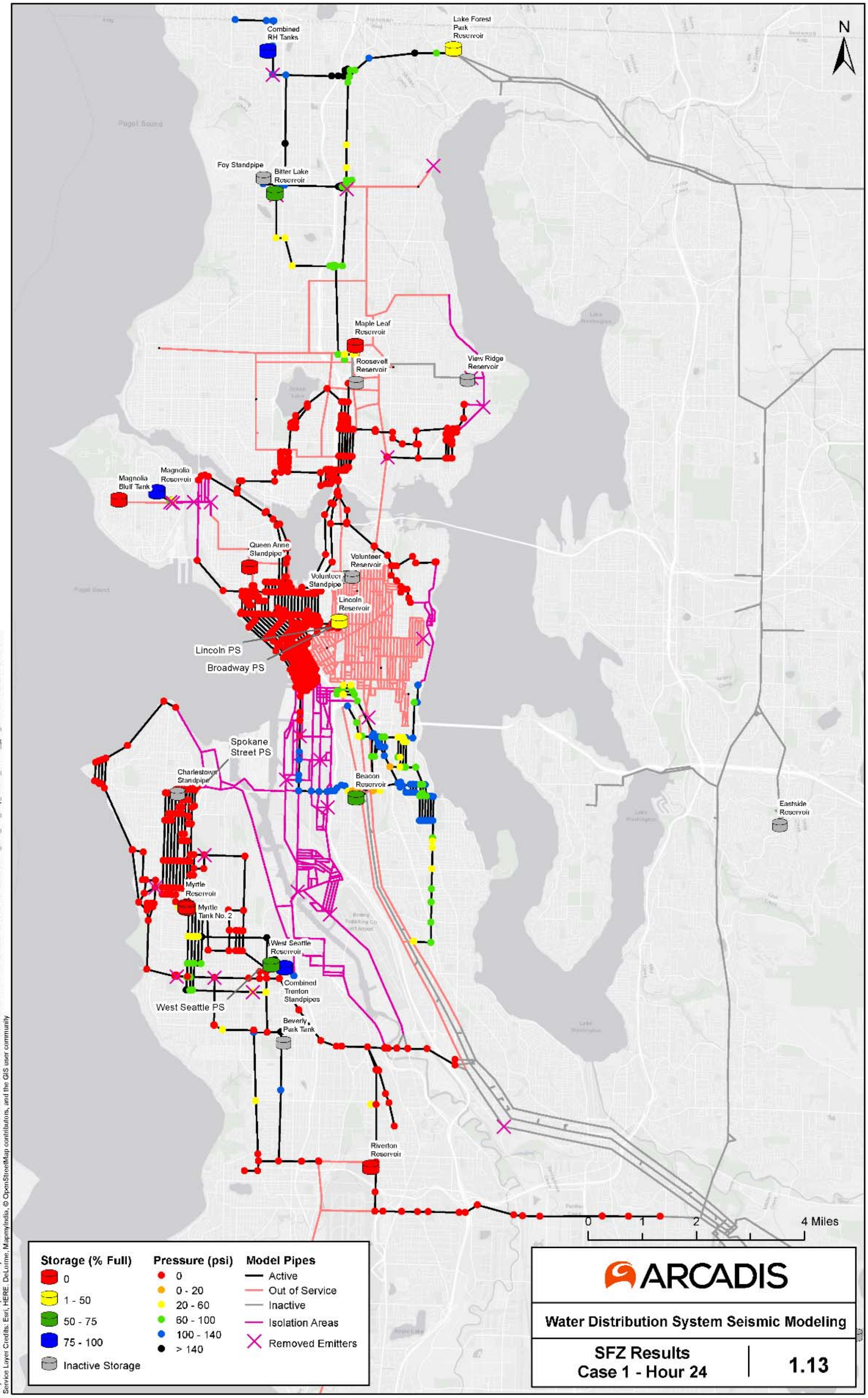

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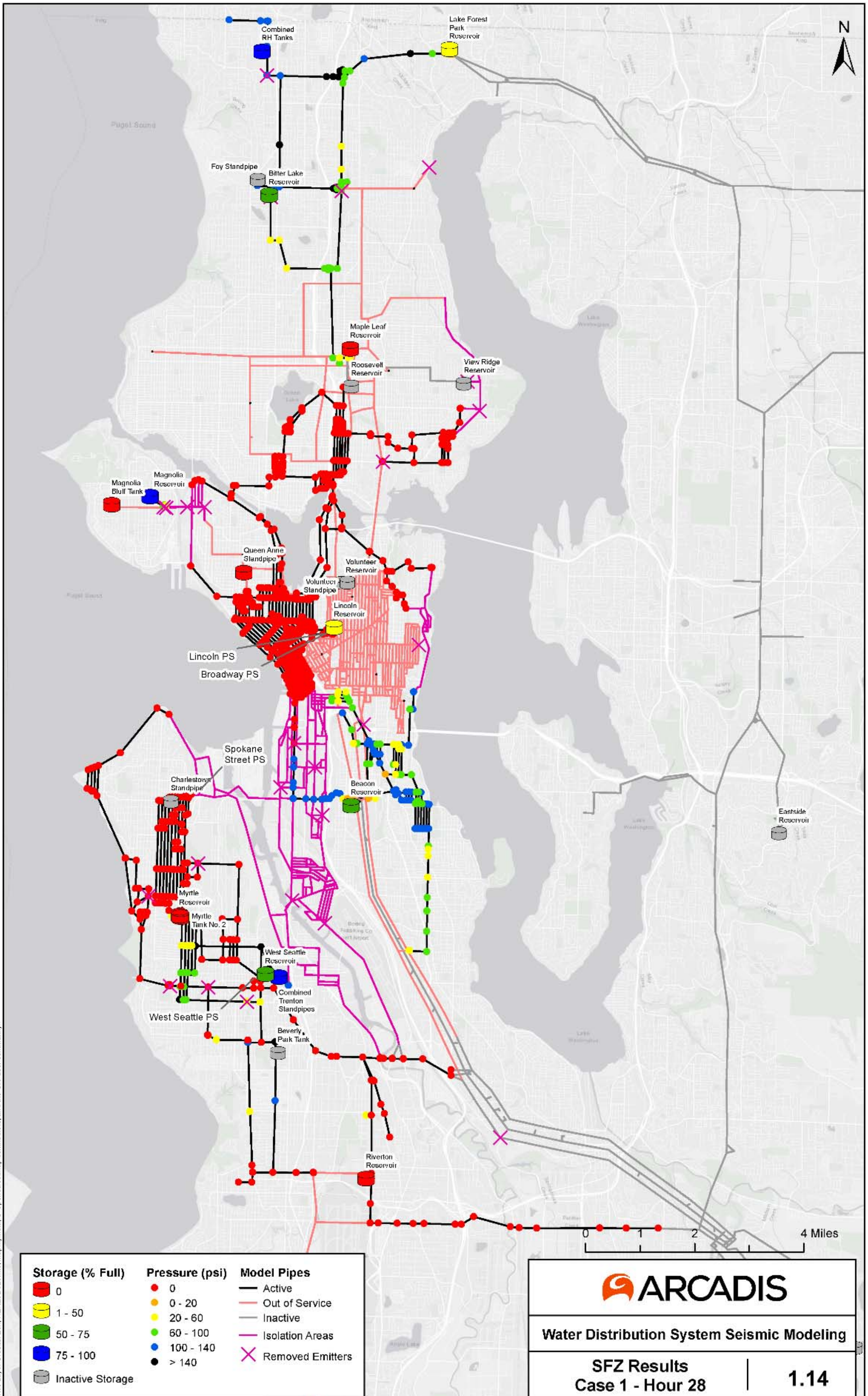

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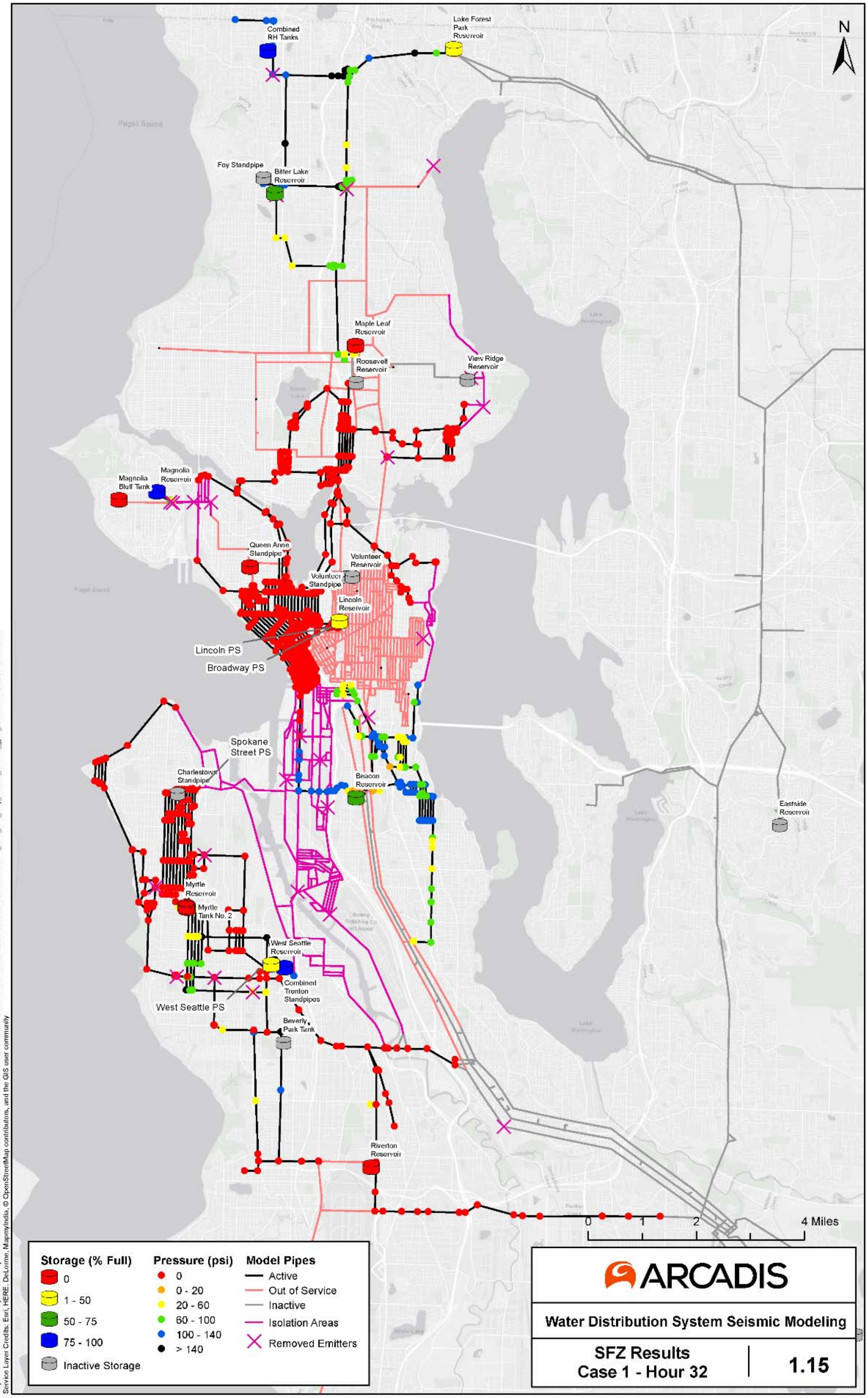

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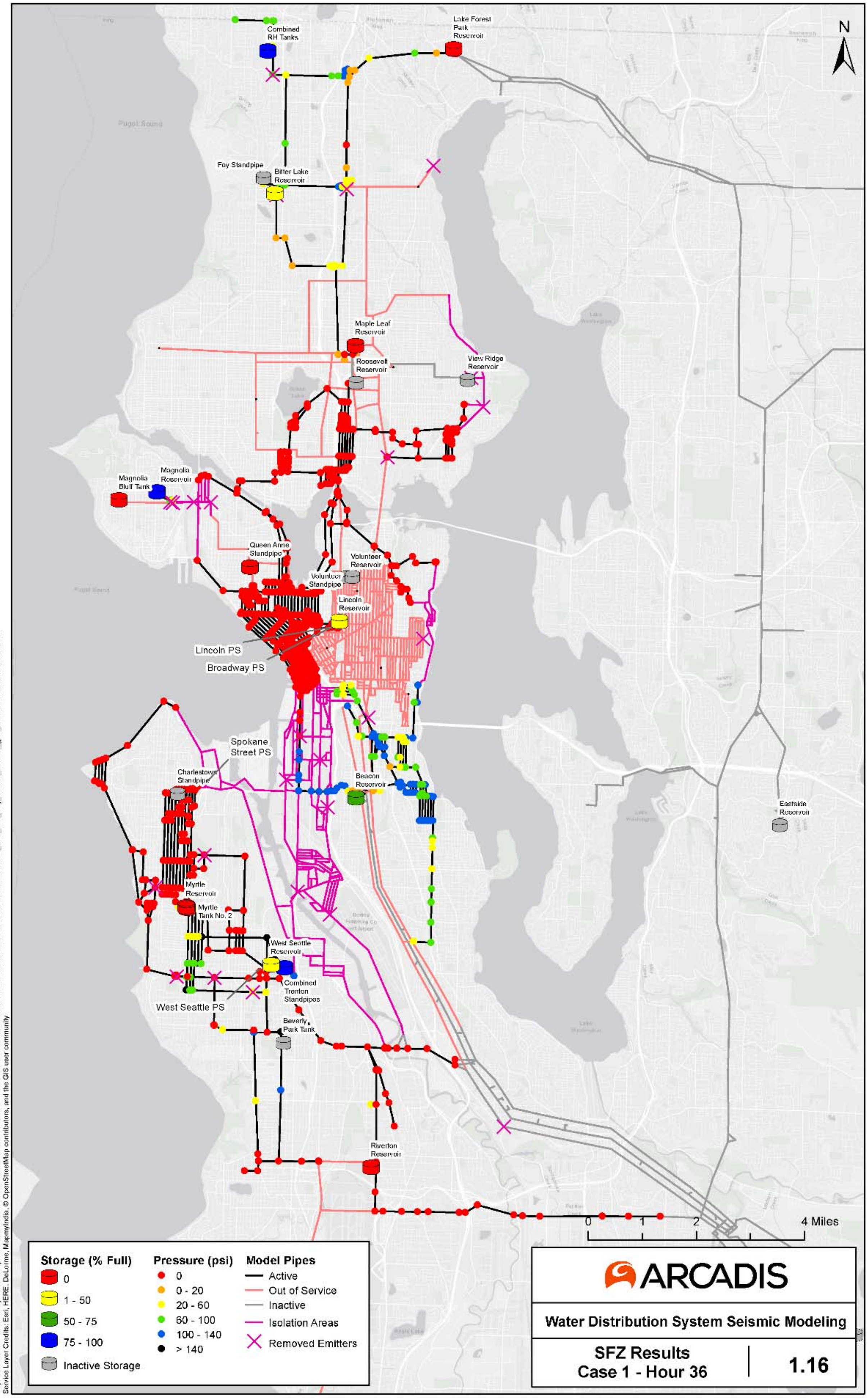

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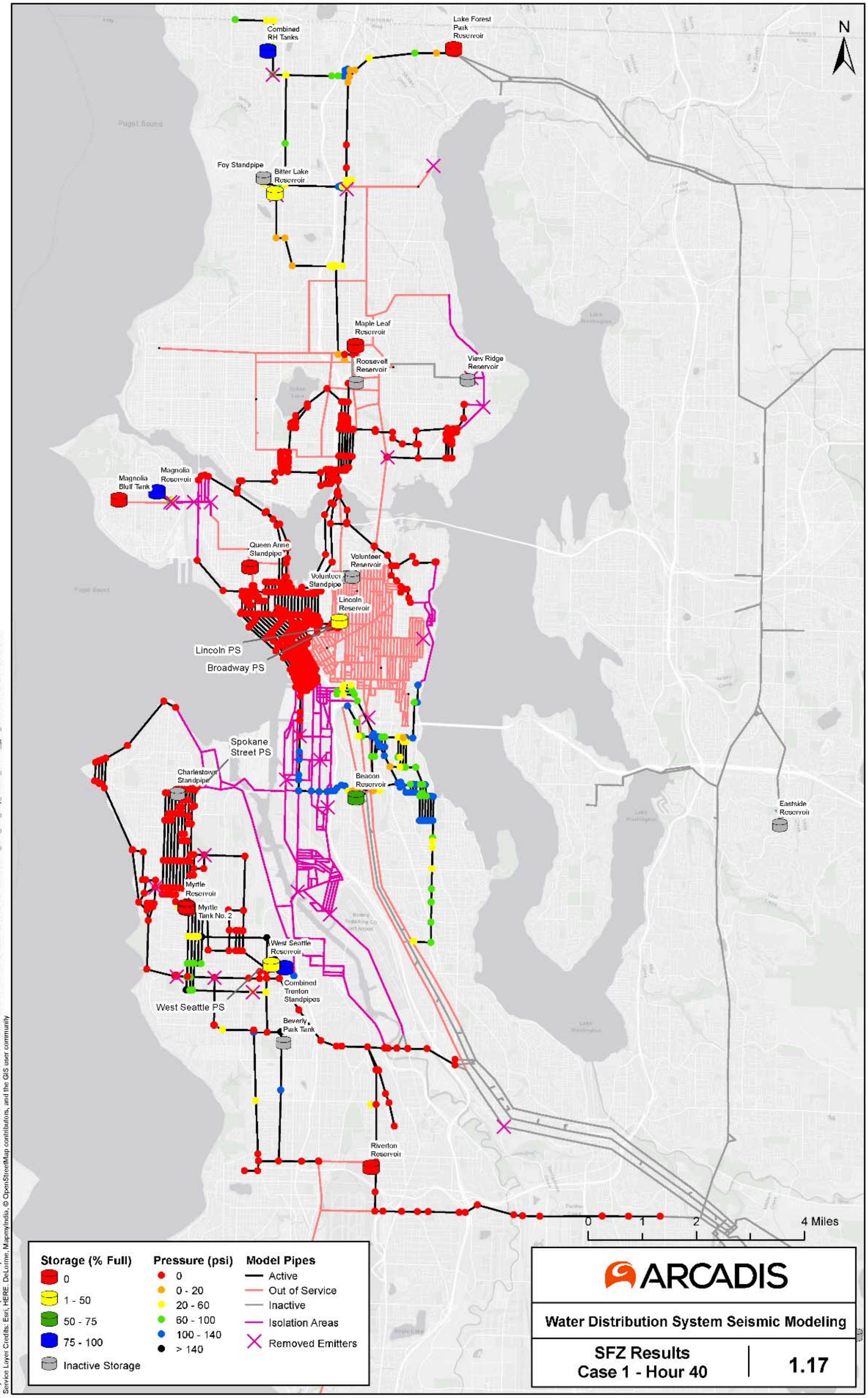
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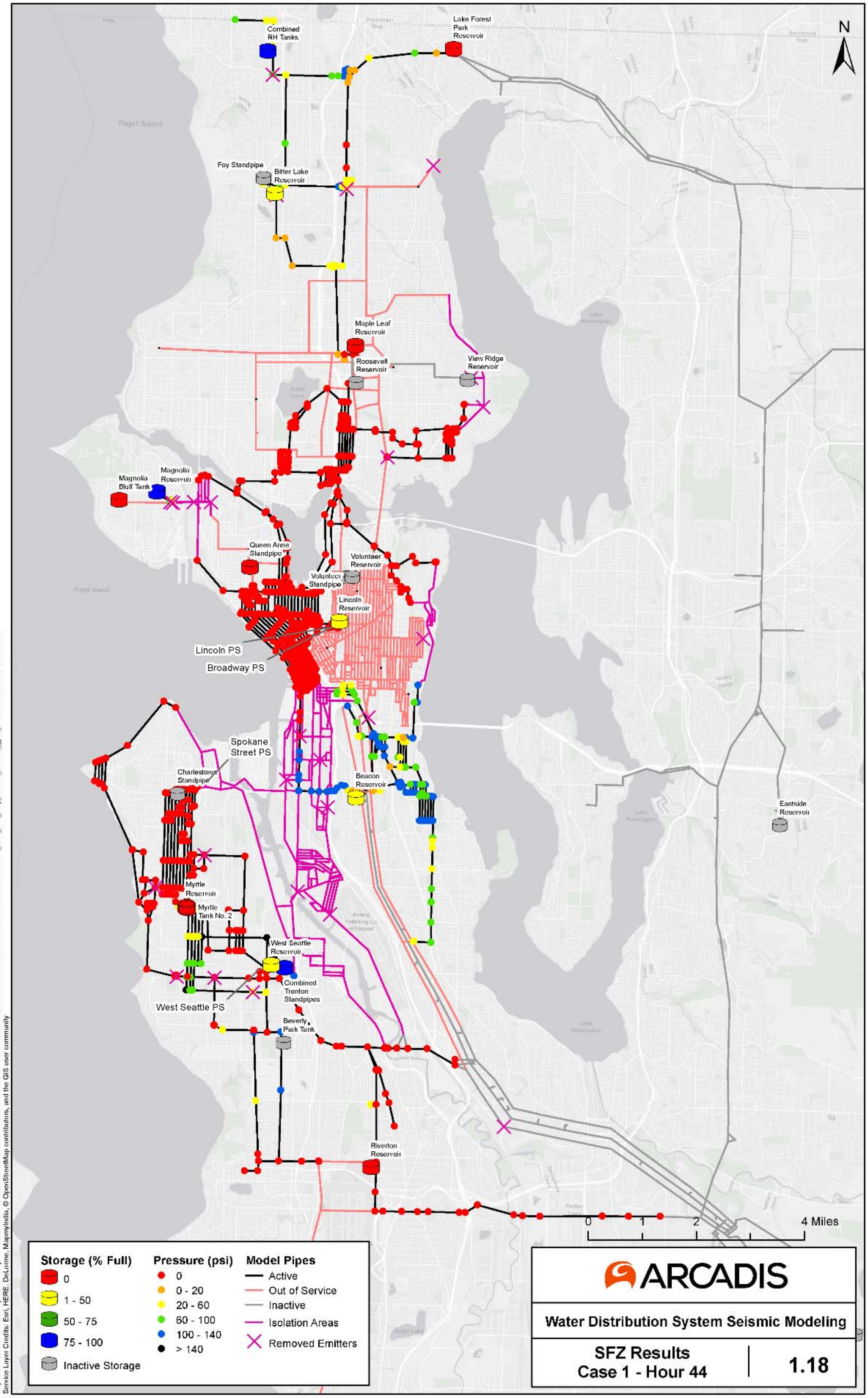
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Lincoln PS
Broadway PS
Spokane Street PS
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
West Seattle PS
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
1 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
Removed Emitters
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 1 - Hour 40
1.17



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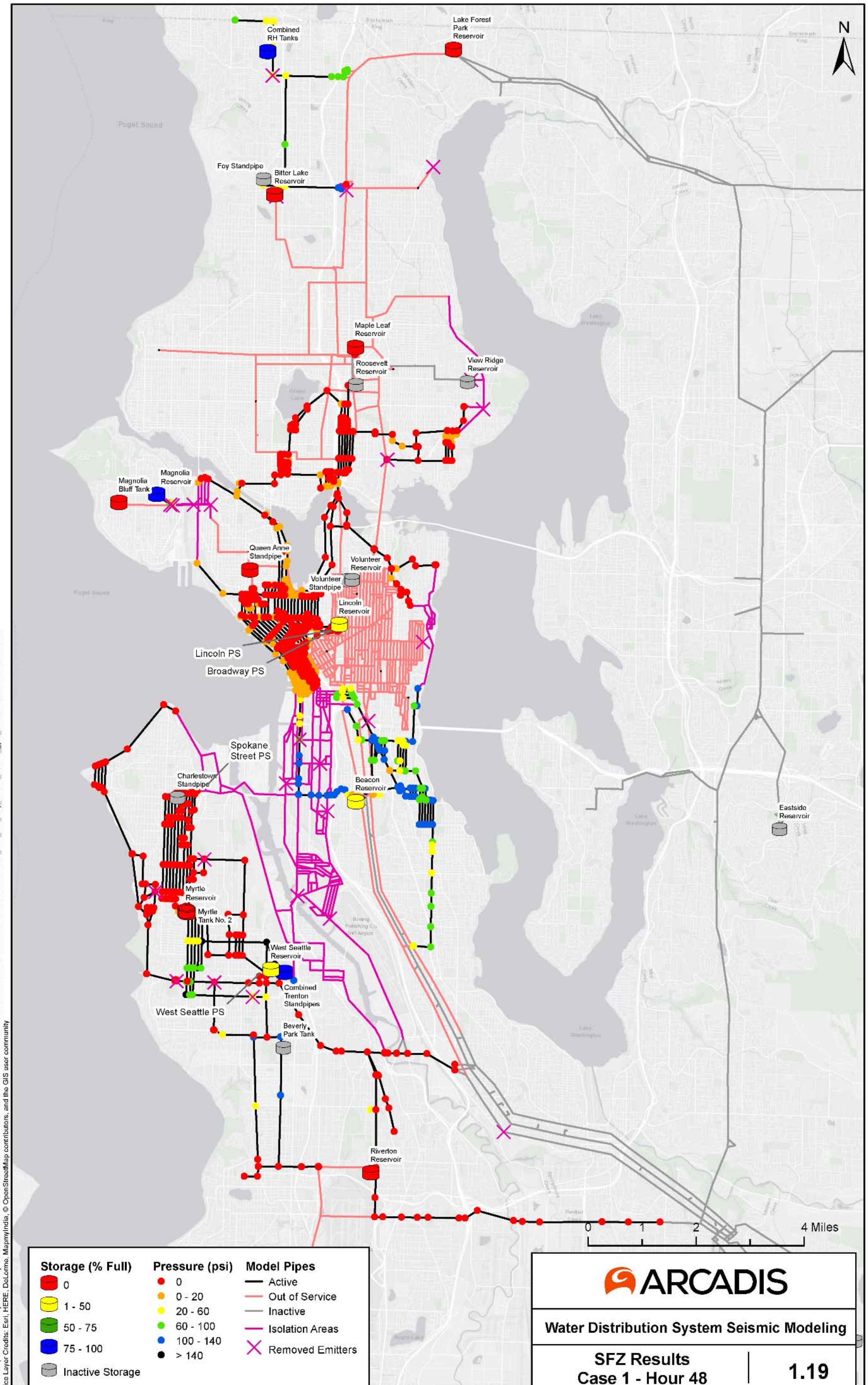

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M7.0 Seattle Fault Zone Case 2 (50 Year Improvements) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

1/26/2018

Seattle Fault Seismic Event

Case 2 Isolation and Control and All Critical Facility Upgrades

Cedar River Pipeline #2 Functional and West Seattle Pipeline Functional

Assume that certain emitters are now zero and that certain areas are automatically isolated to prevent leakage

All facilities shown below are now functional

In Service Storage	*In Service Facilities*
Eastside Reservoir	Lincoln PS
Magnolia Bluff Elevated Tank	Broadway PS
Magnolia Reservoir	Spokane Street PS
Riverton Heights Reservoir	West Seattle PS
Beverly Park Elevated Tank	Trenton PS
Charlestown Standpipe	Augusta PS
Foy Standpipe	Fairwood PS
View Ridge Reservoir	
Volunteer Park Standpipe	

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	166,493	135,655	30,838	90%	294.3
3	153,225	122,708	30,517	90%	273.6
12	139,924	109,922	30,002	86%	219.7
22	133,403	104,028	29,375	83%	162.6
32	89,645	69,424	20,222	56%	119.8
48	50,748	34,795	15,954	48%	87.0

Model Regions Forced Out of Service During Simulation

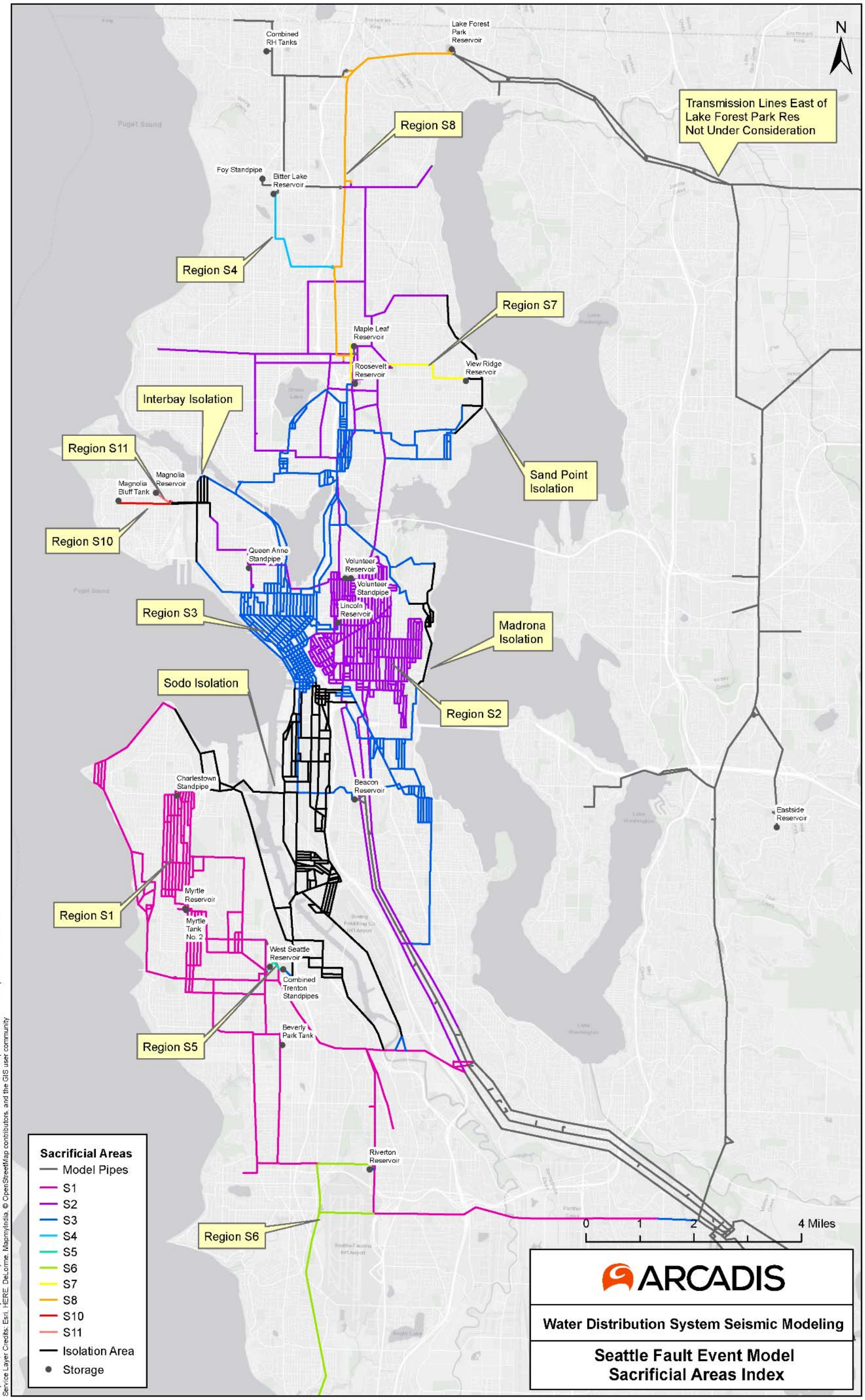
Time	Region
22	S7
24	S11
27	S6
47	S4
47	S8

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 2.1	Hr 0	Fig. 2.5	Hr 8	Fig. 2.9	Hr 16	Fig. 2.13	Hr 24	Fig. 2.17	Hr 40
Fig. 2.2	Hr 2	Fig. 2.6	Hr 10	ig. 2.10	Hr 18	Fig. 2.14	Hr 28	Fig. 2.18	Hr 44
Fig. 2.3	Hr 4	Fig. 2.7	Hr 12	ig. 2.11	Hr 20	Fig. 2.15	Hr 32	Fig. 2.19	Hr 48
Fig. 2.4	Hr 6	Fig. 2.8	Hr 14	ig. 2.12	Hr 22	Fig. 2.16	Hr 36		



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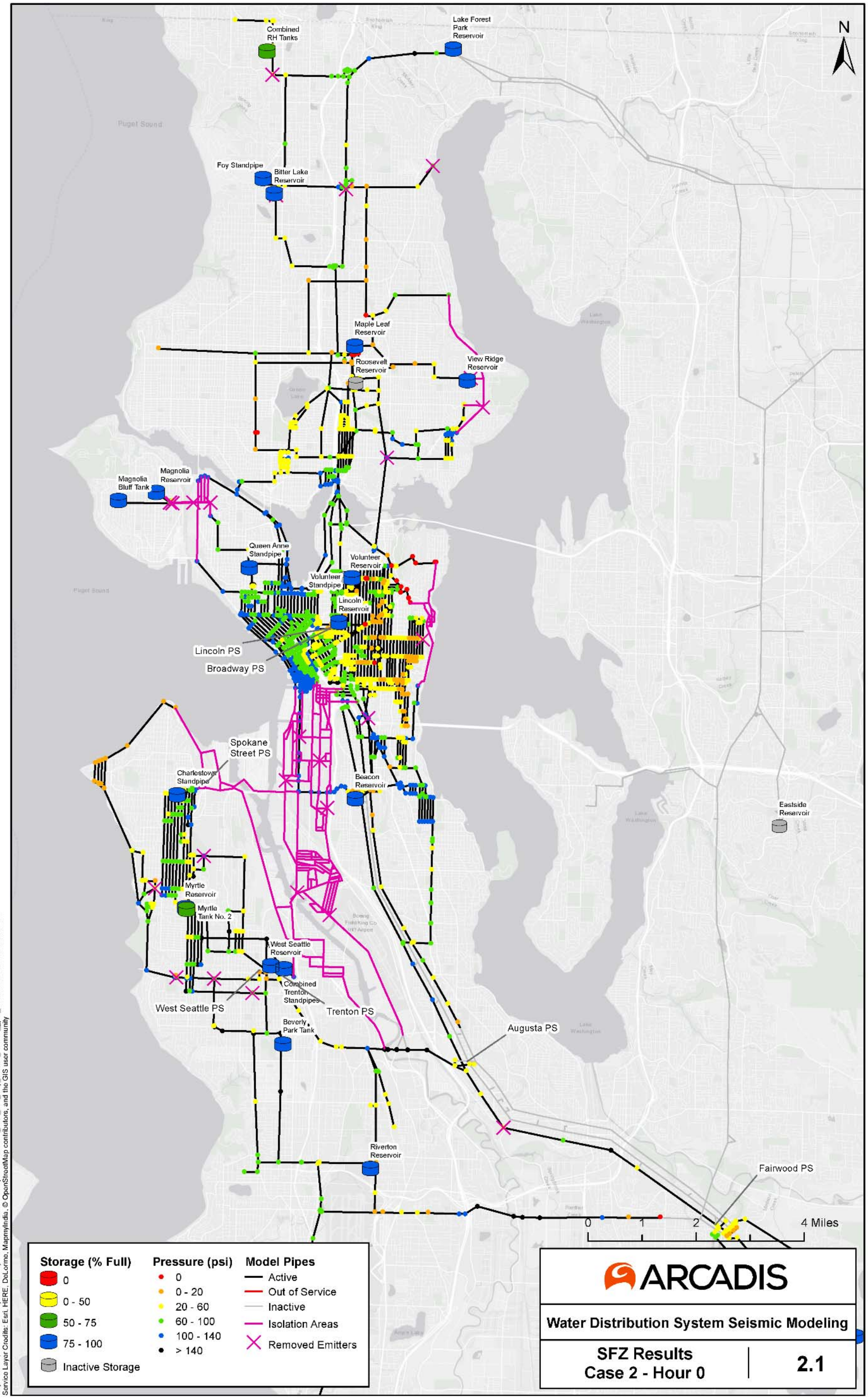
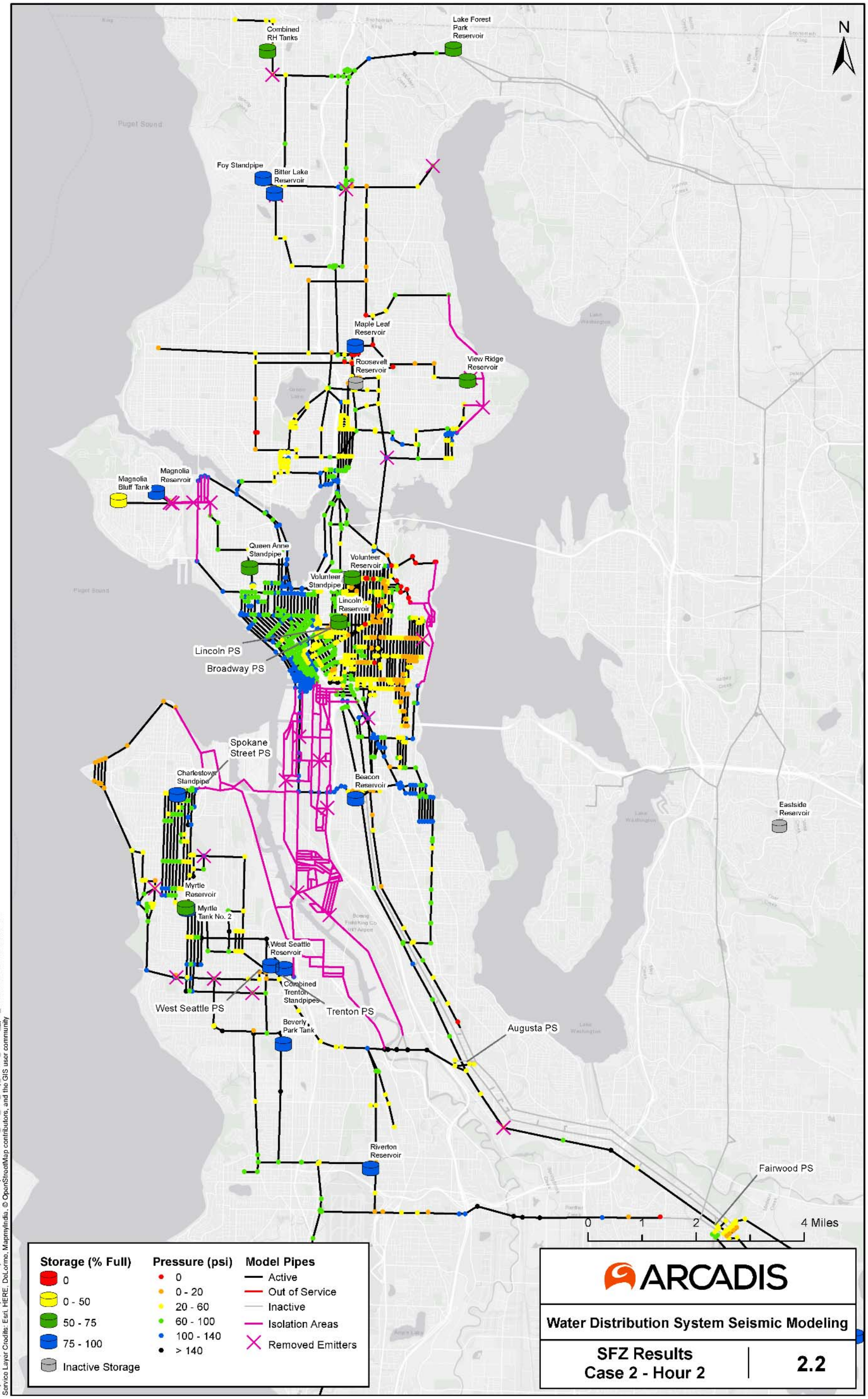


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 2 - Hour 0

2.1



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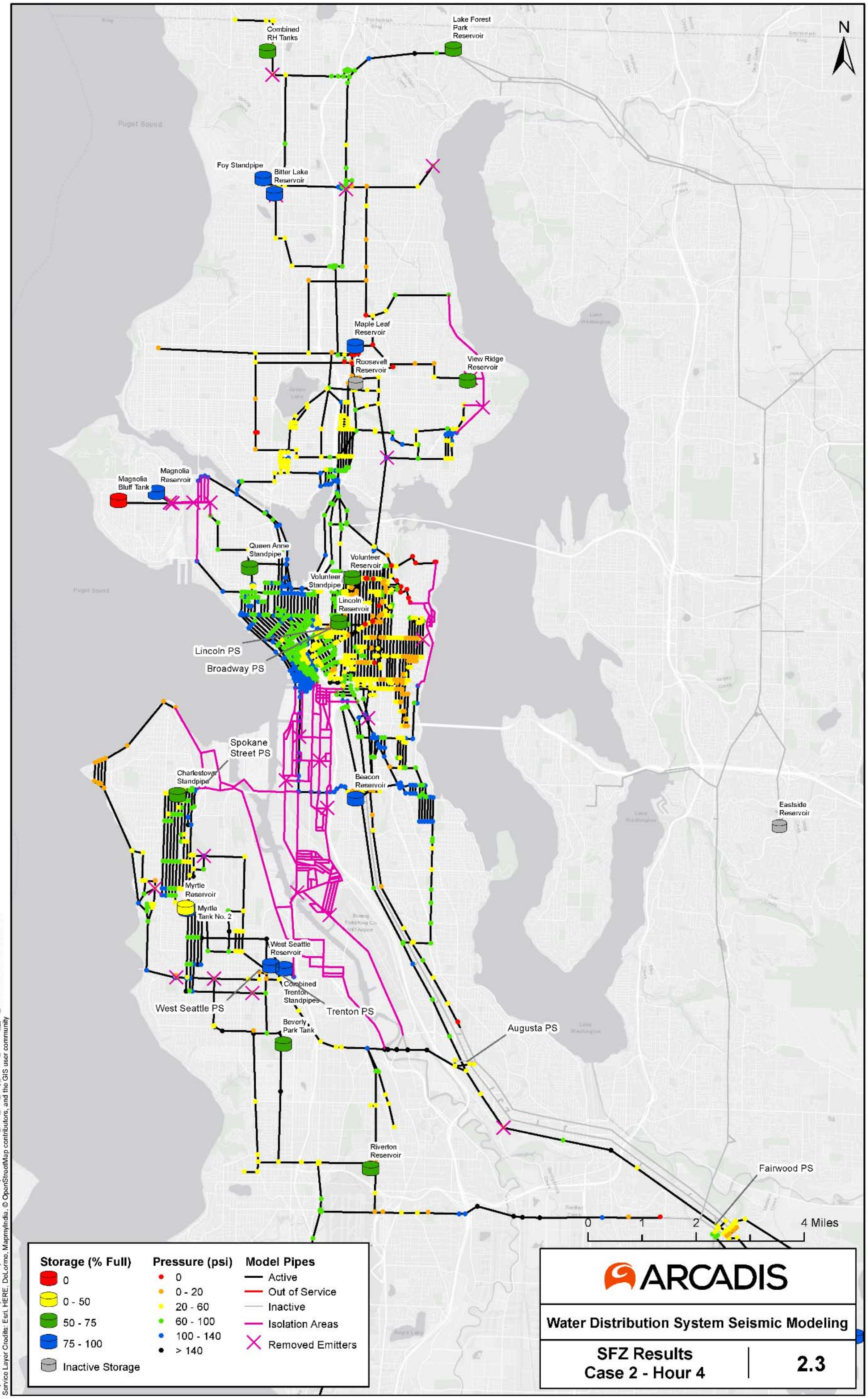

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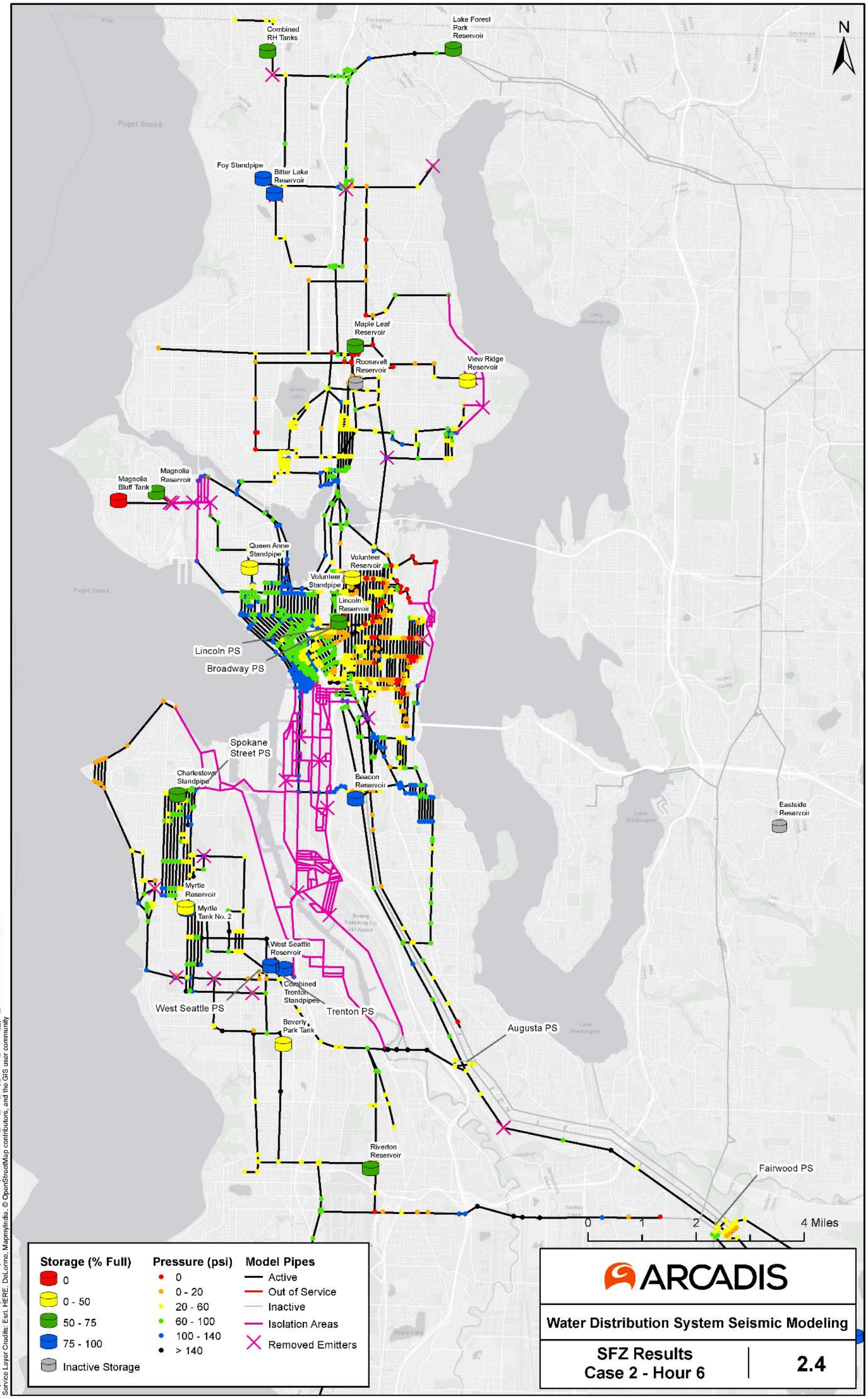

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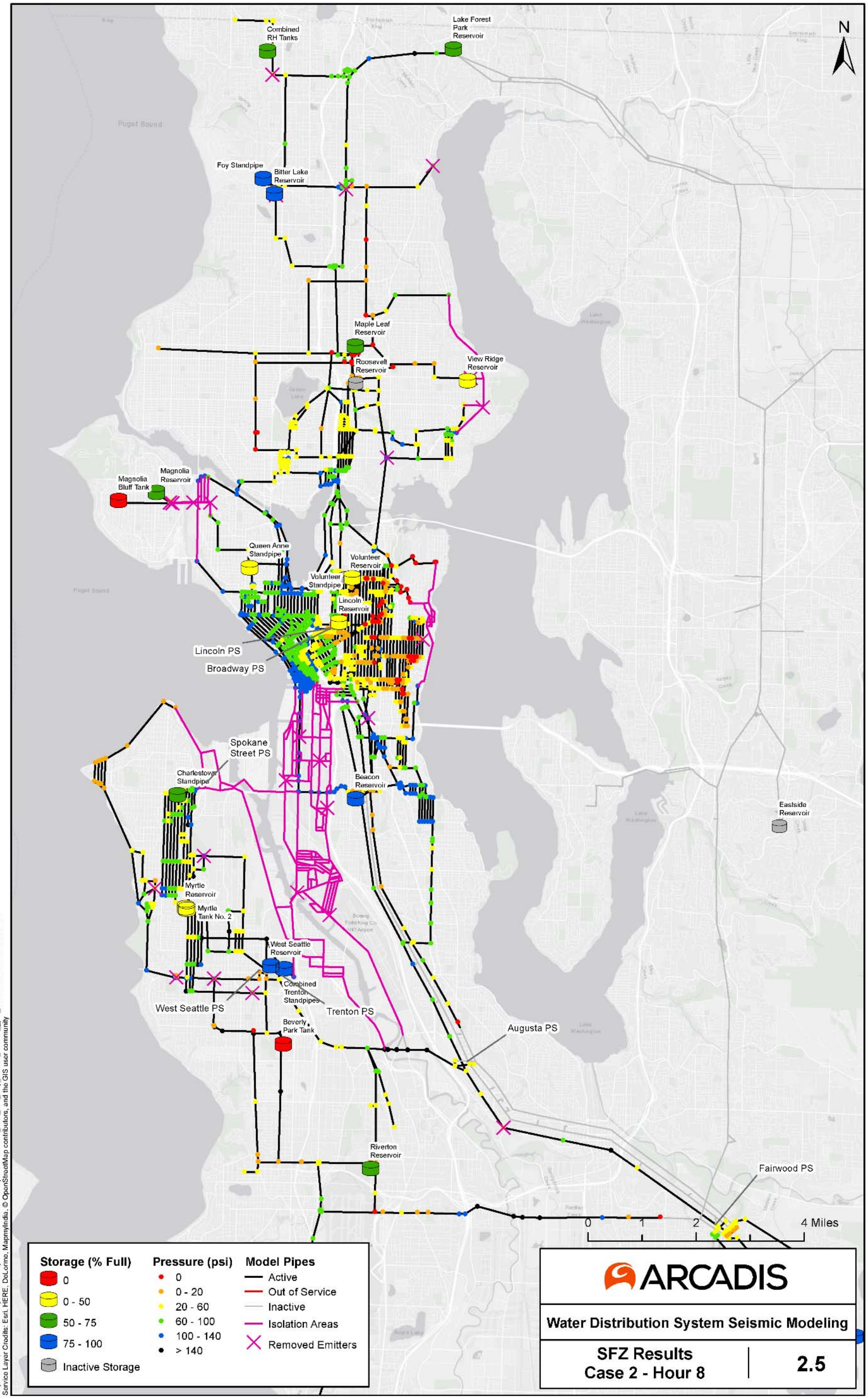

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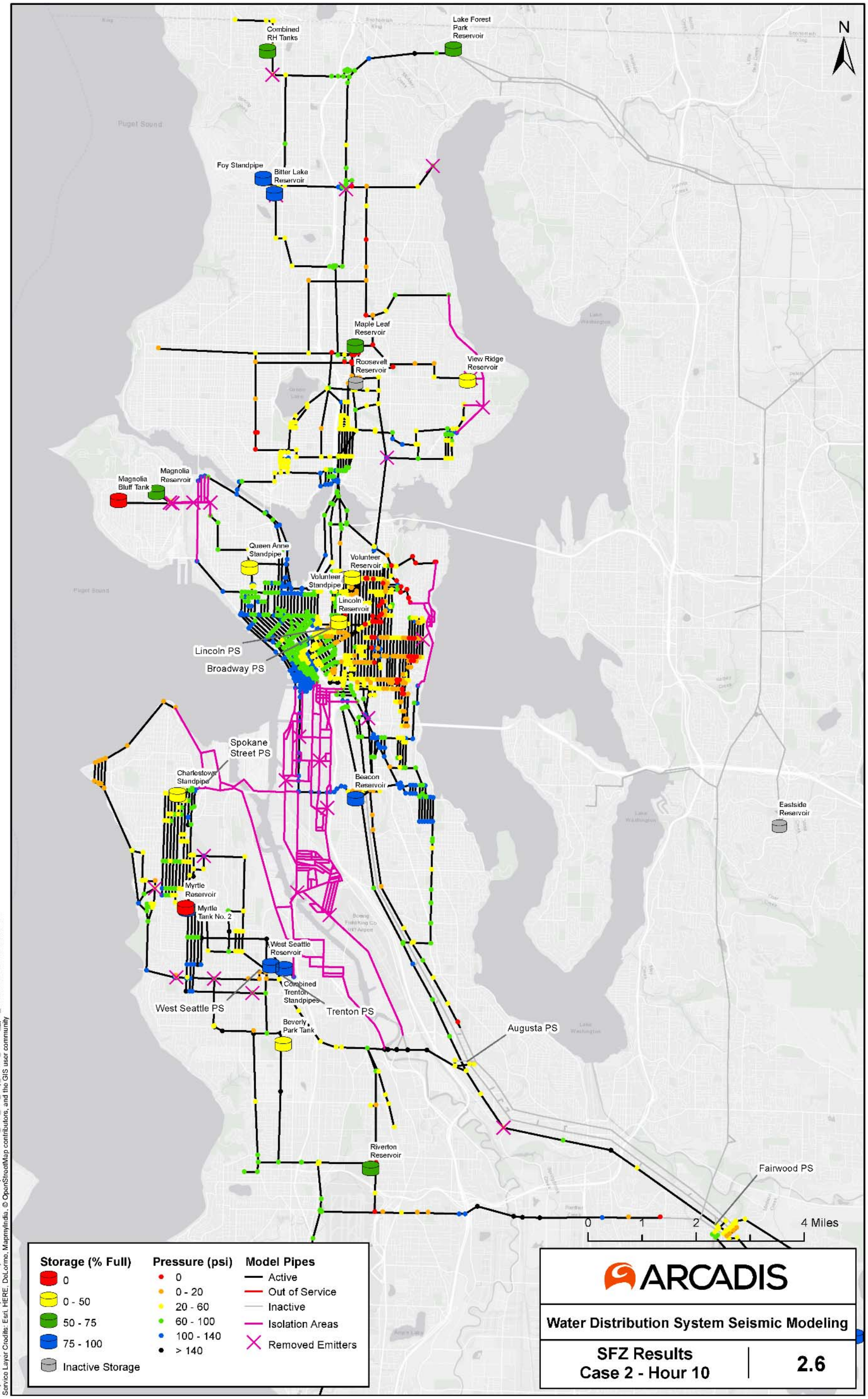

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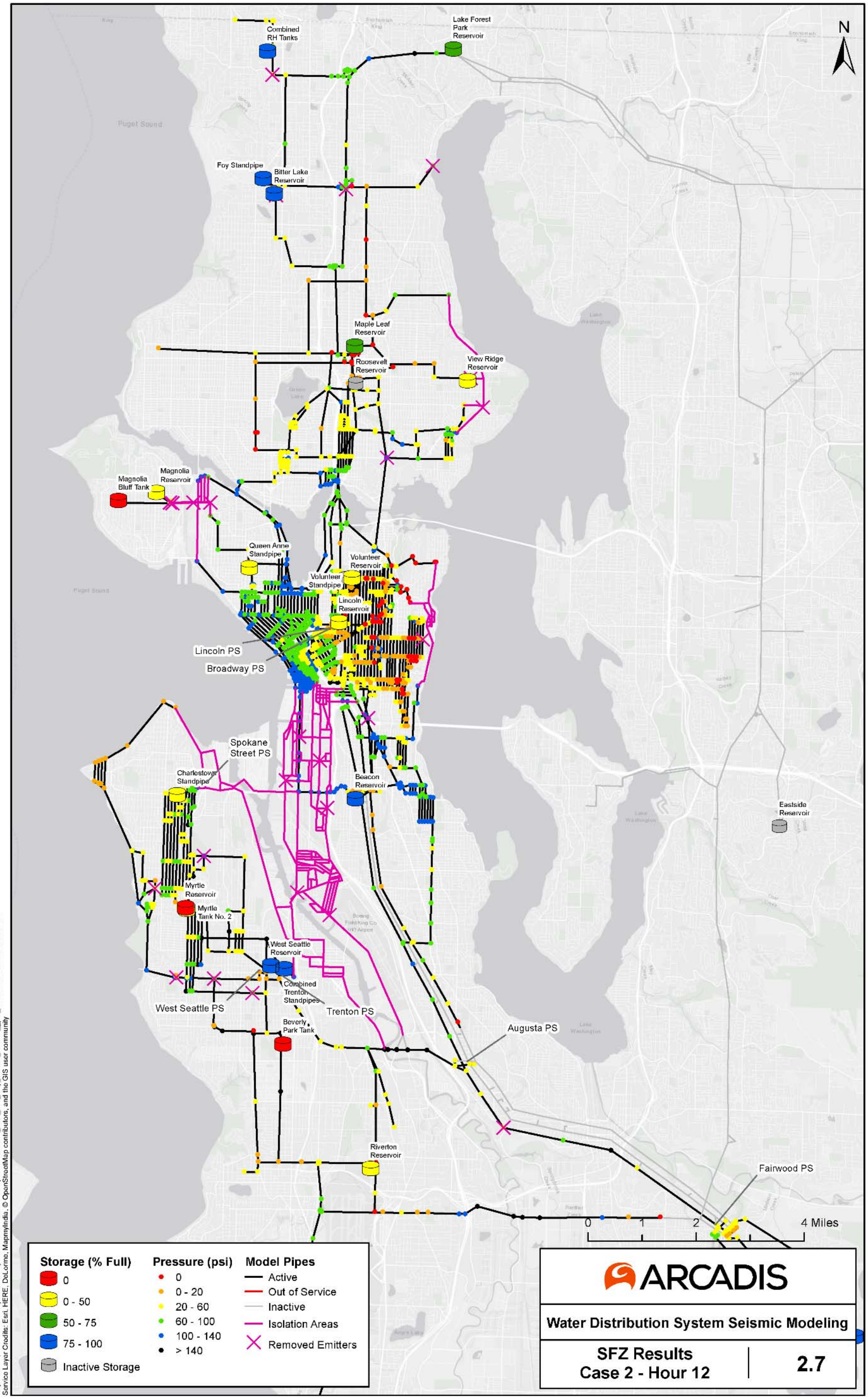

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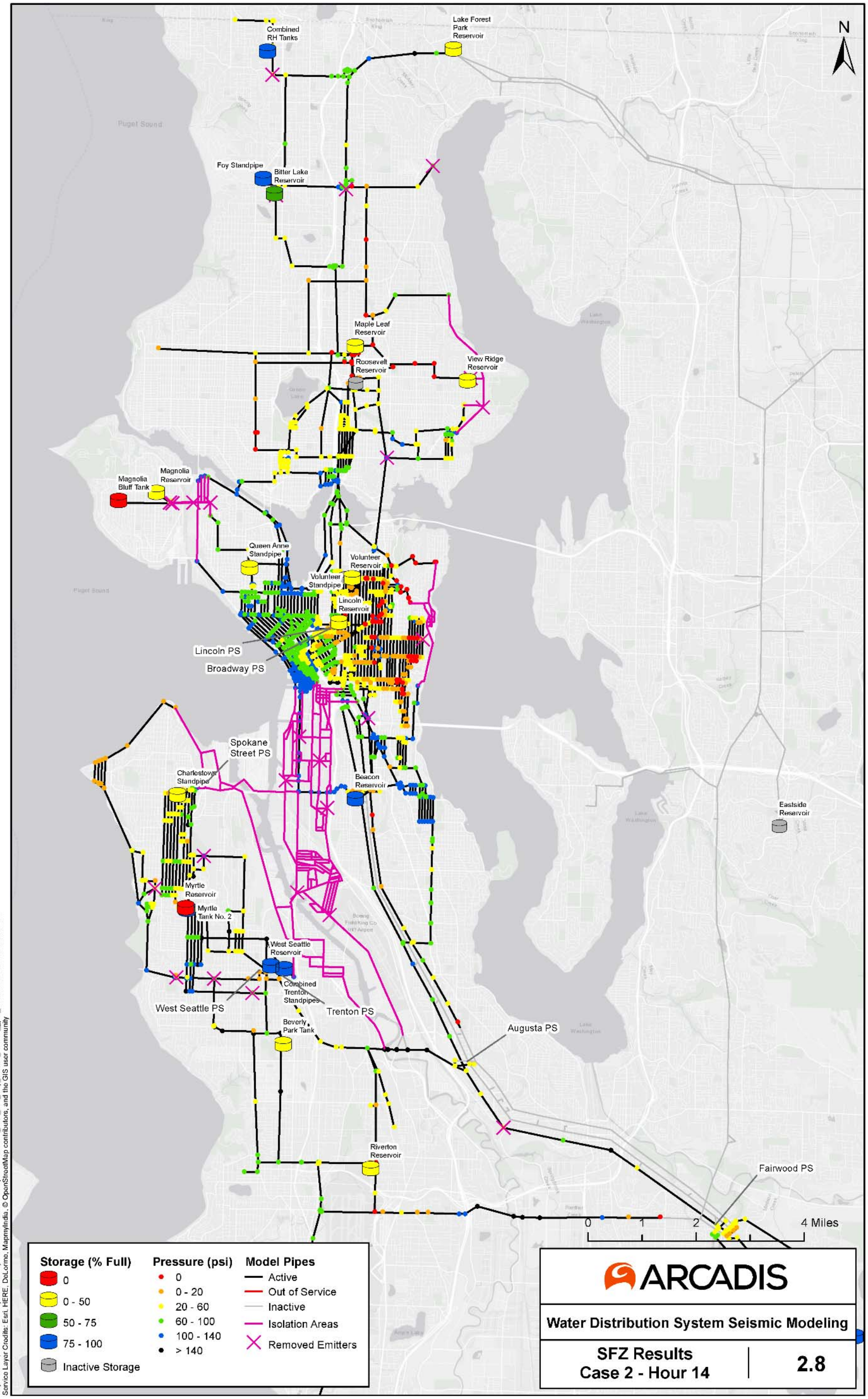

Water Distribution System Seismic Modeling

SFZ Results
Case 2 - Hour 14

2.8

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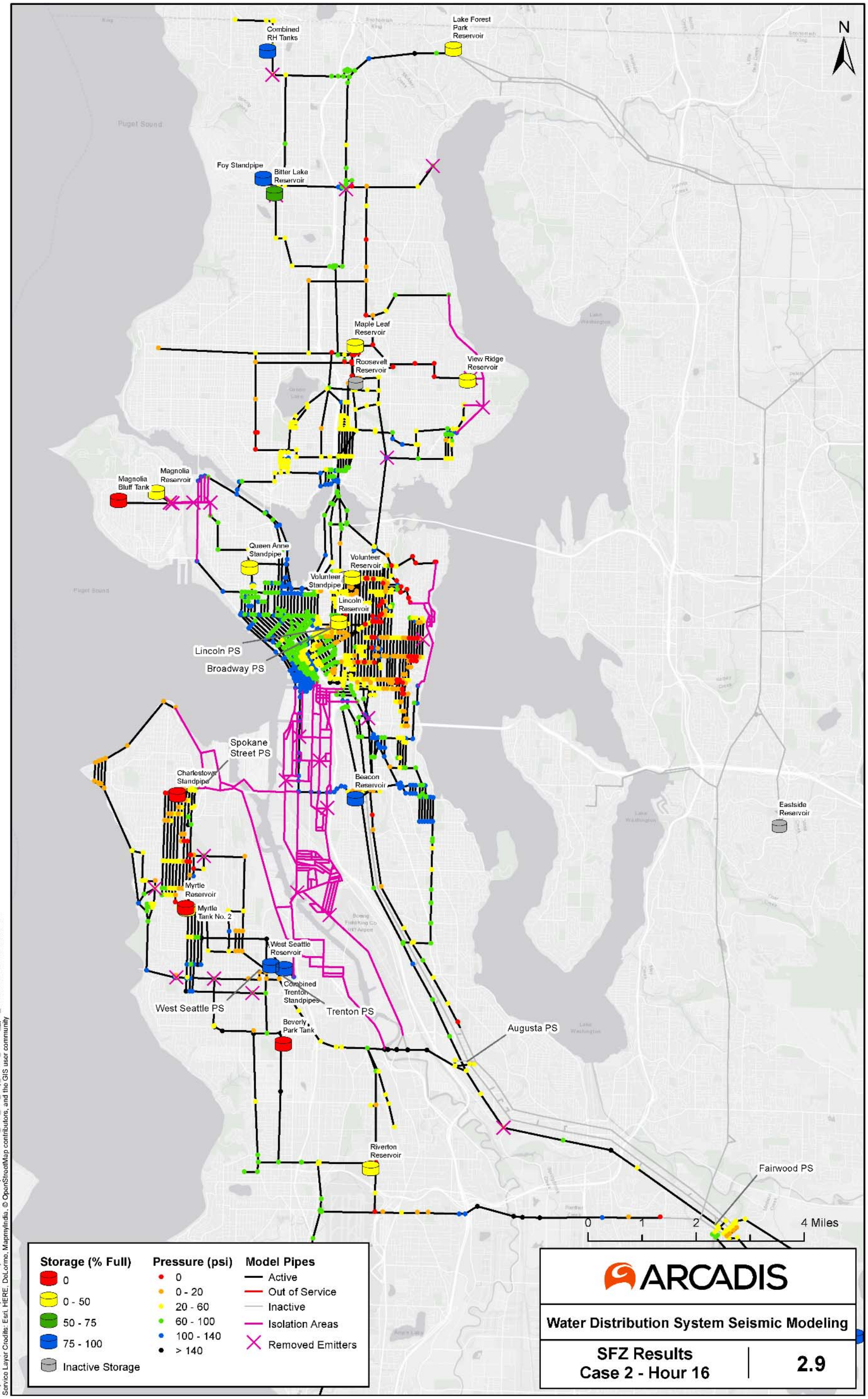

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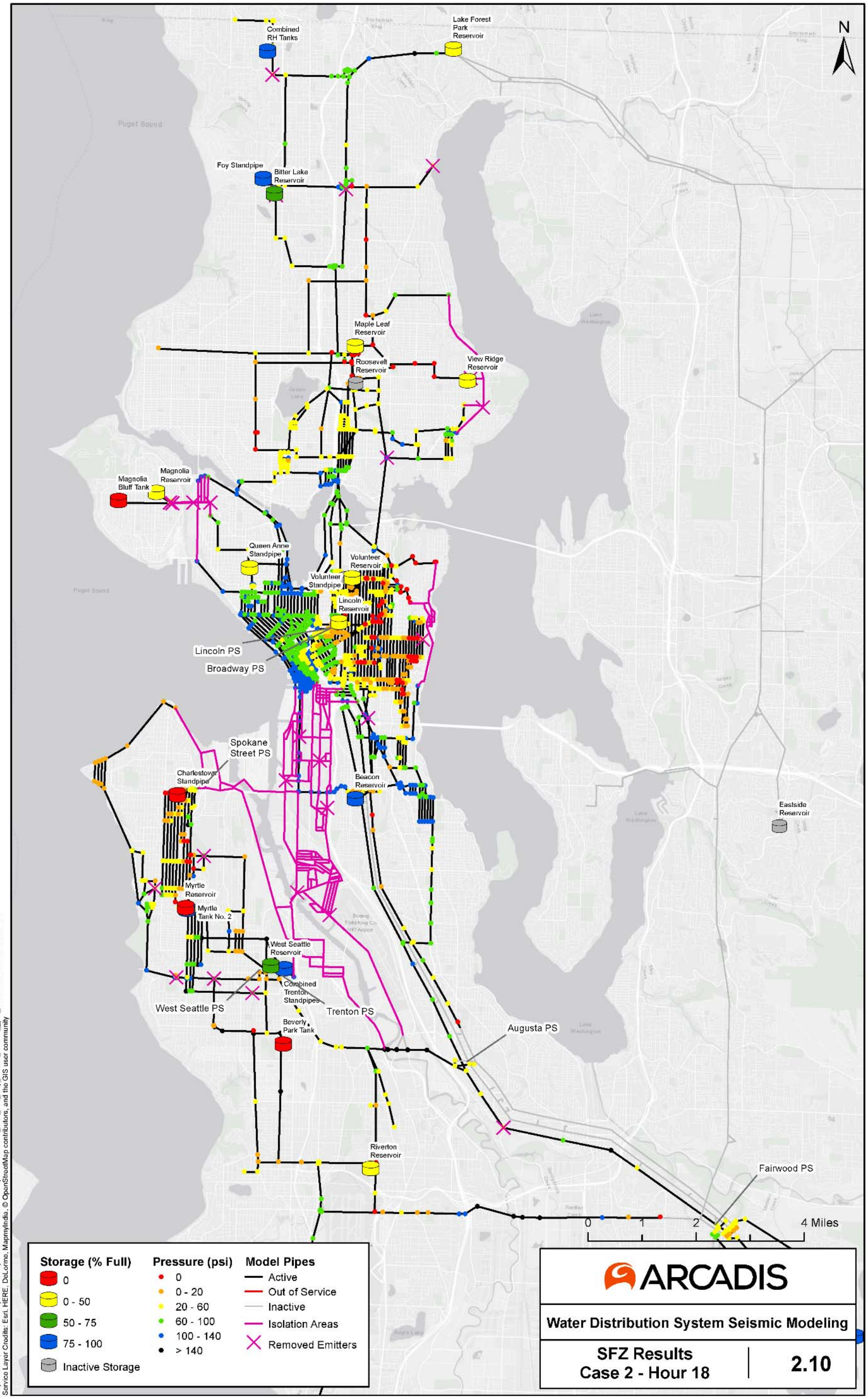

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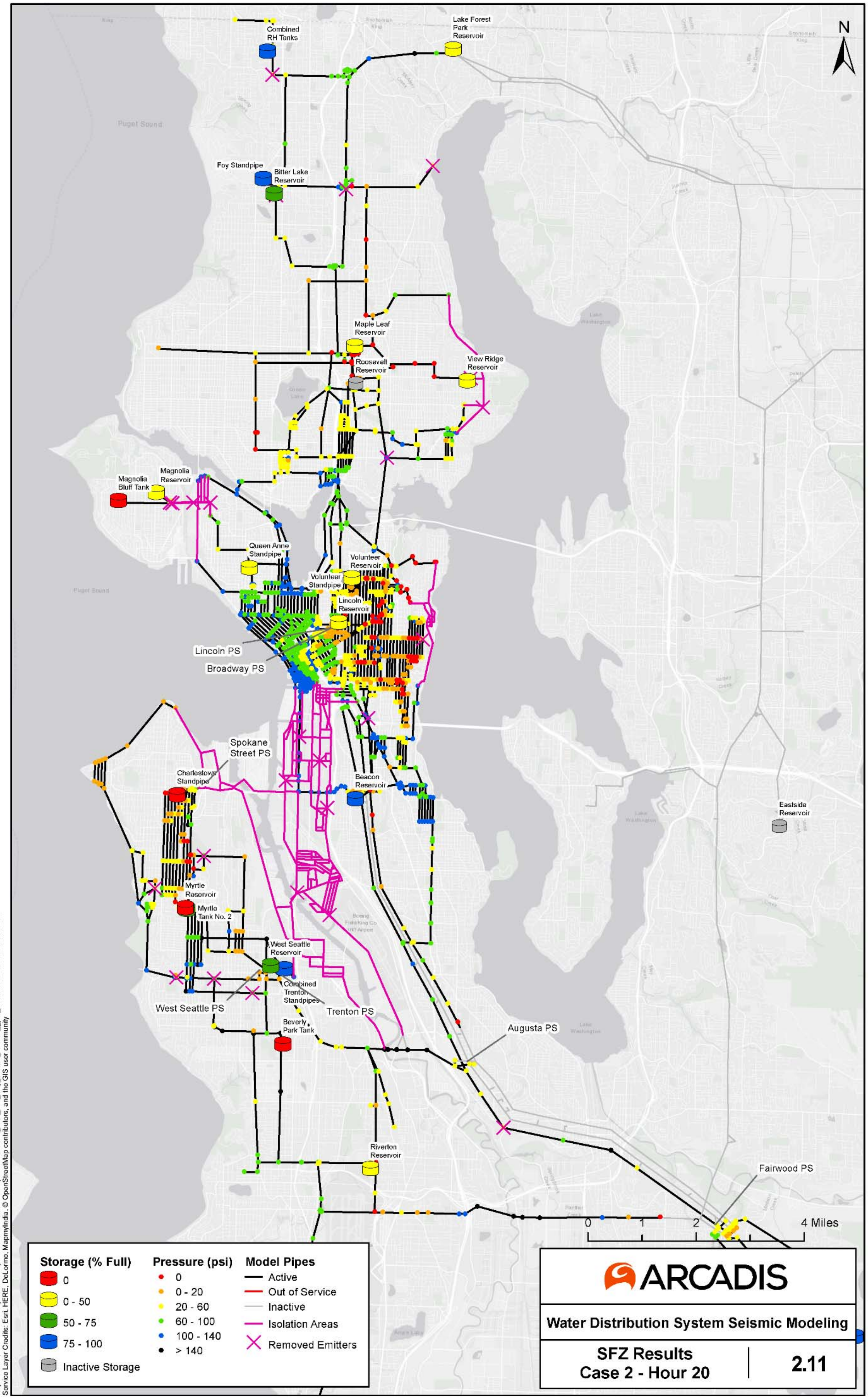

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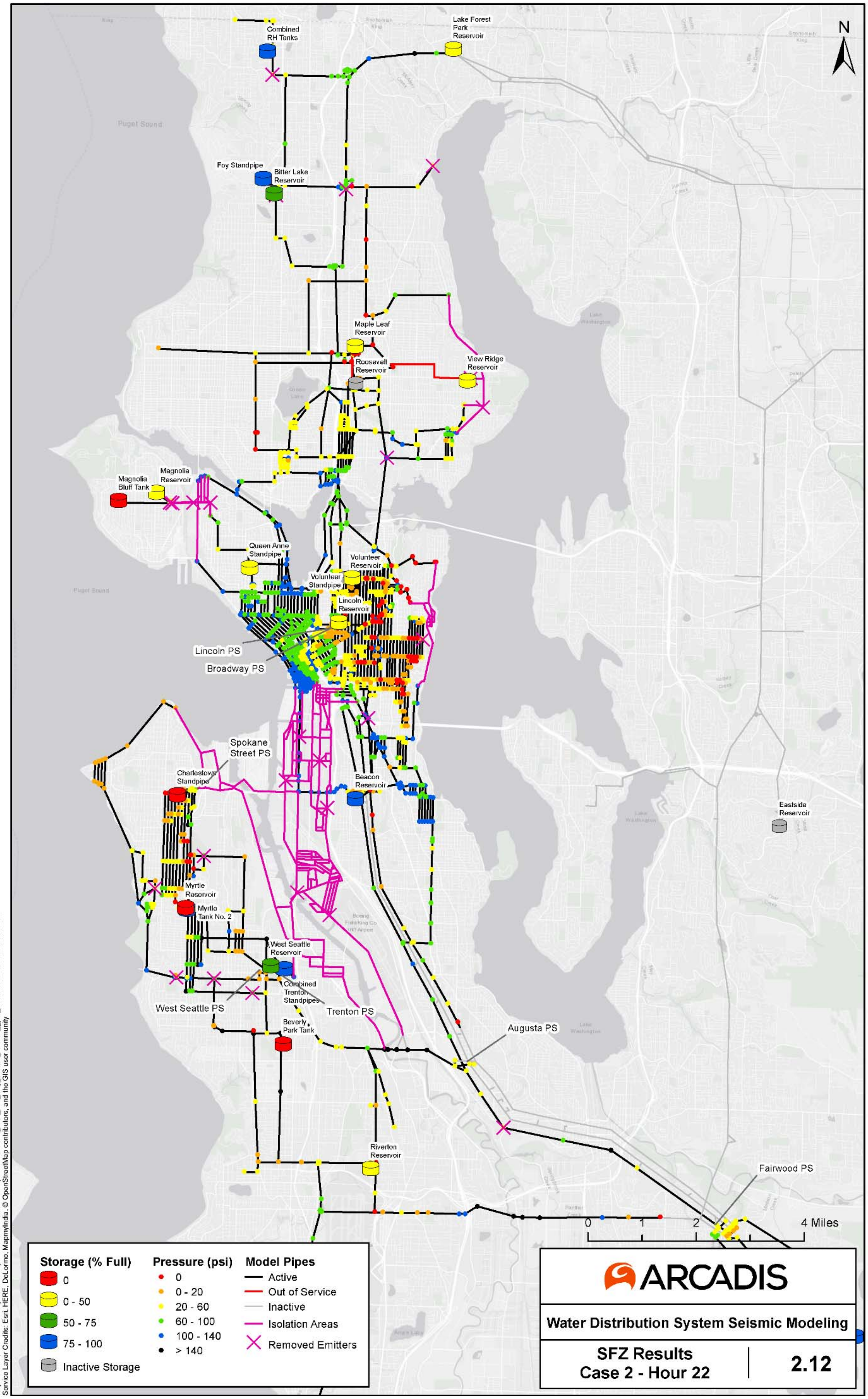

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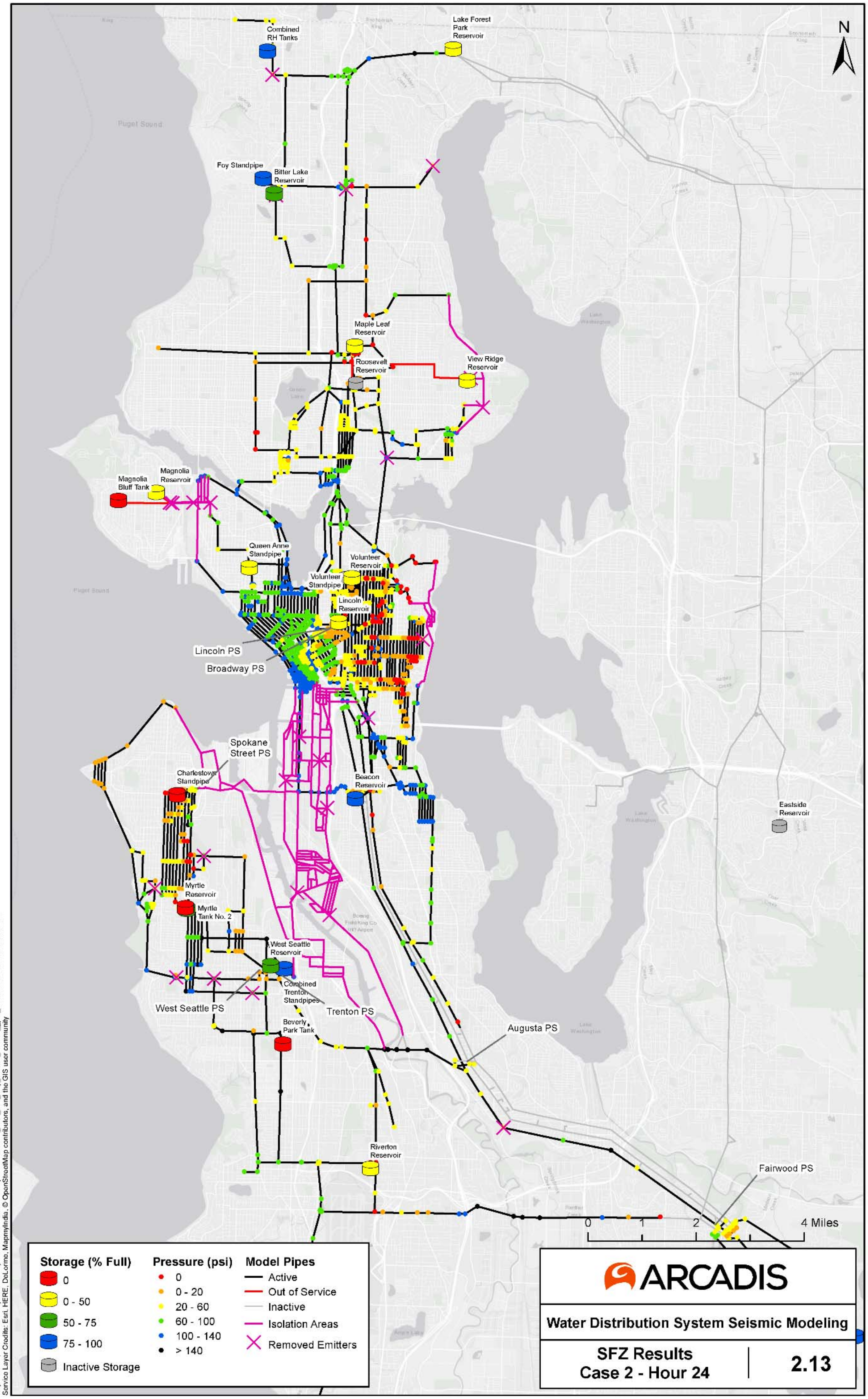

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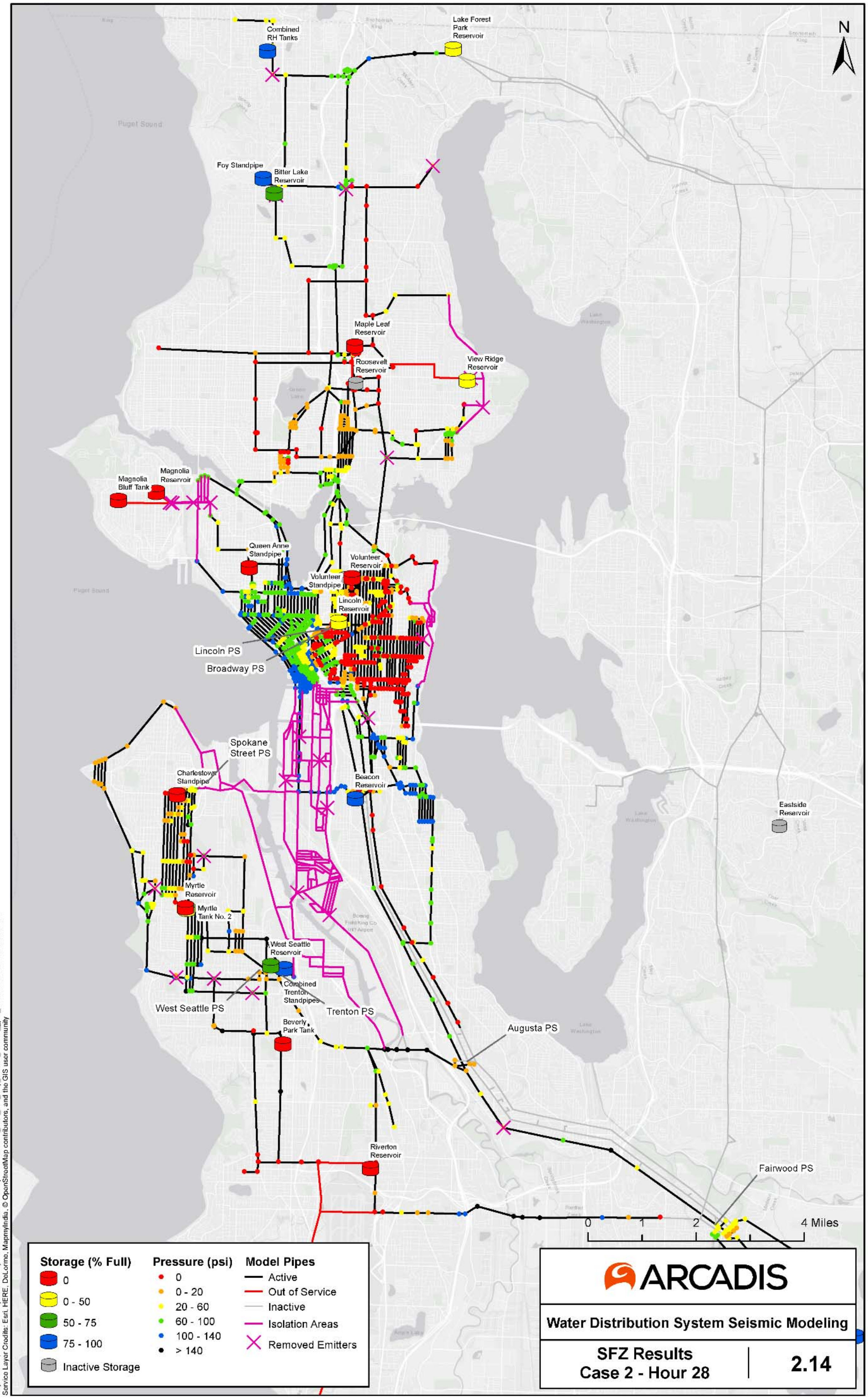

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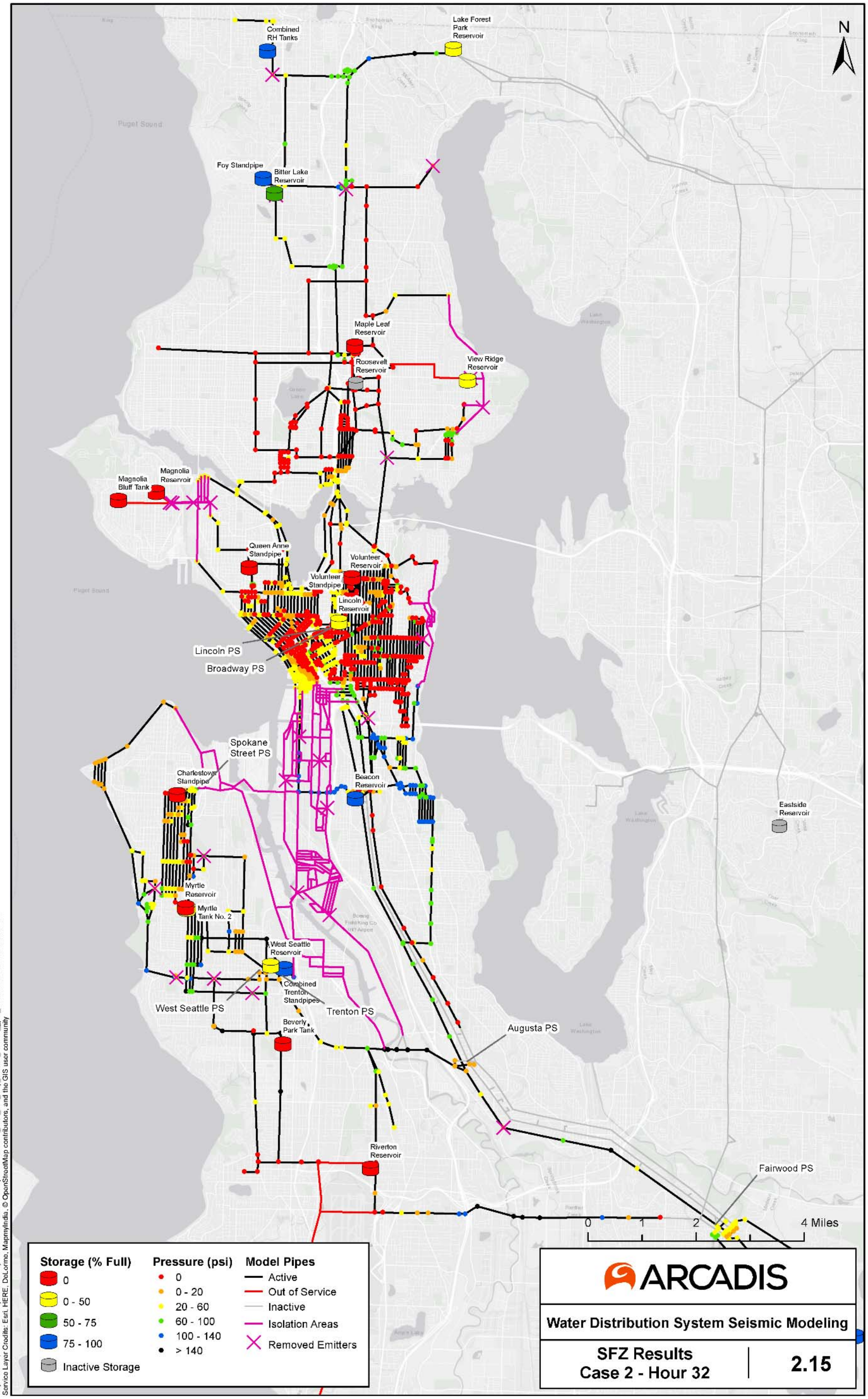

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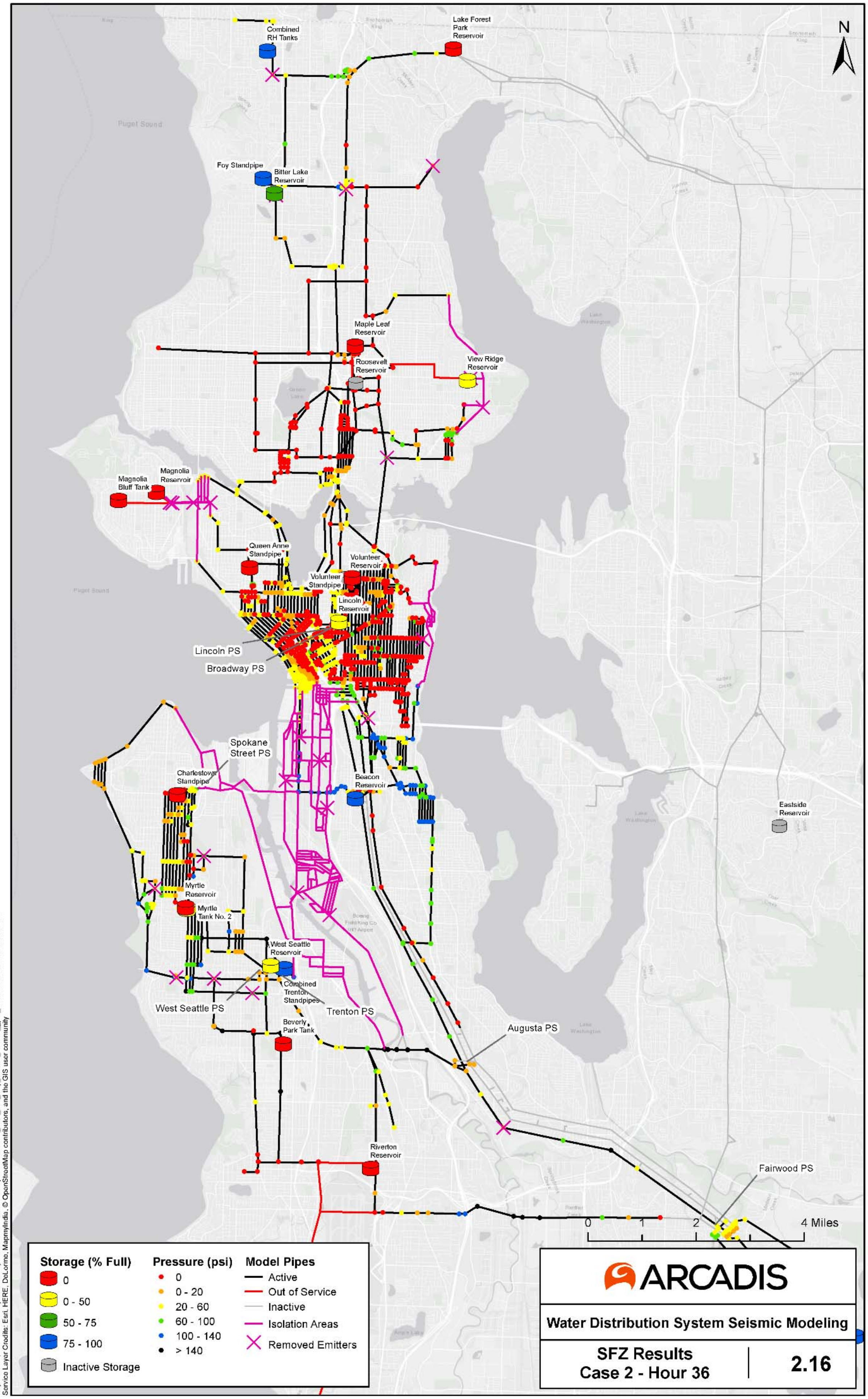

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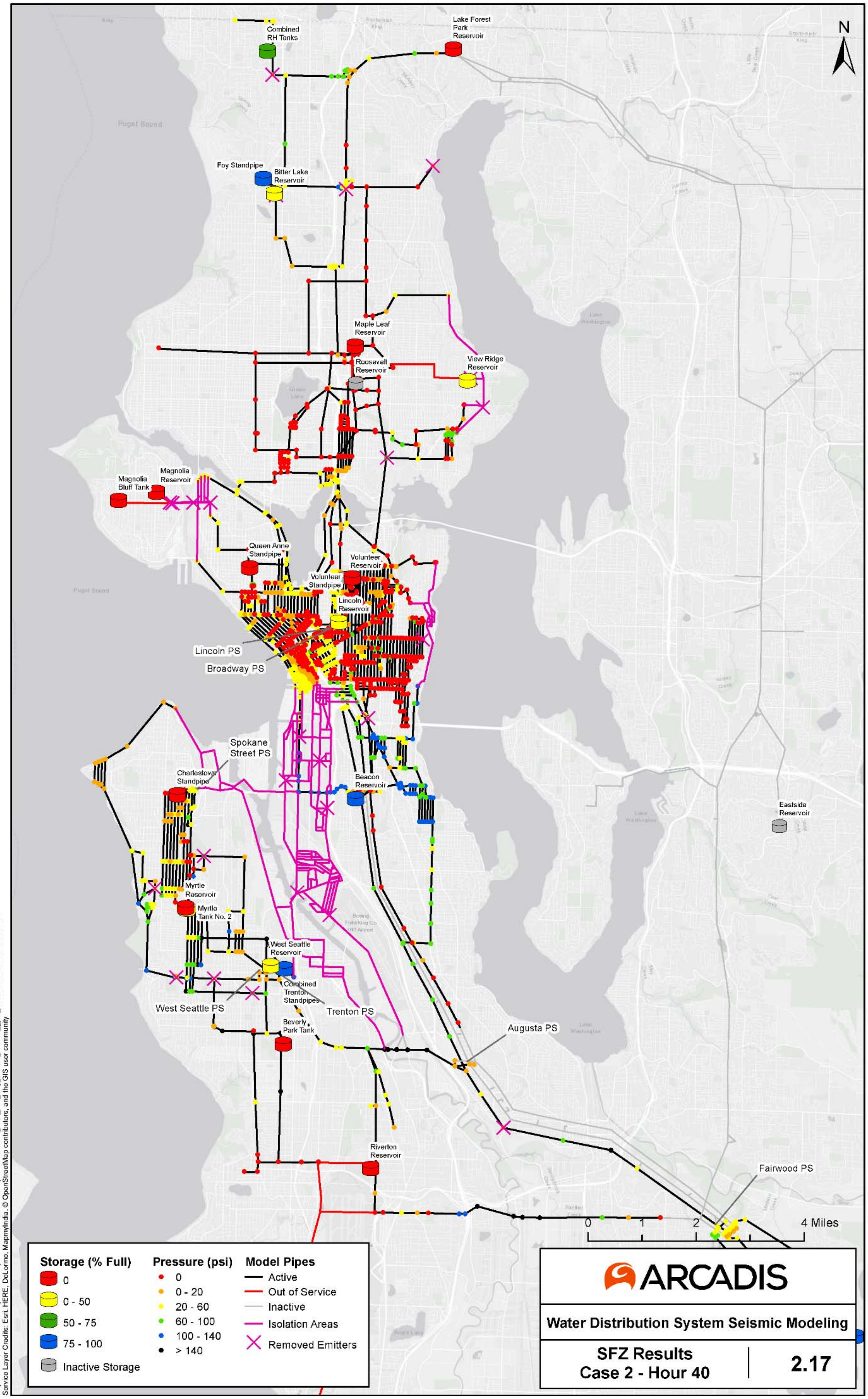

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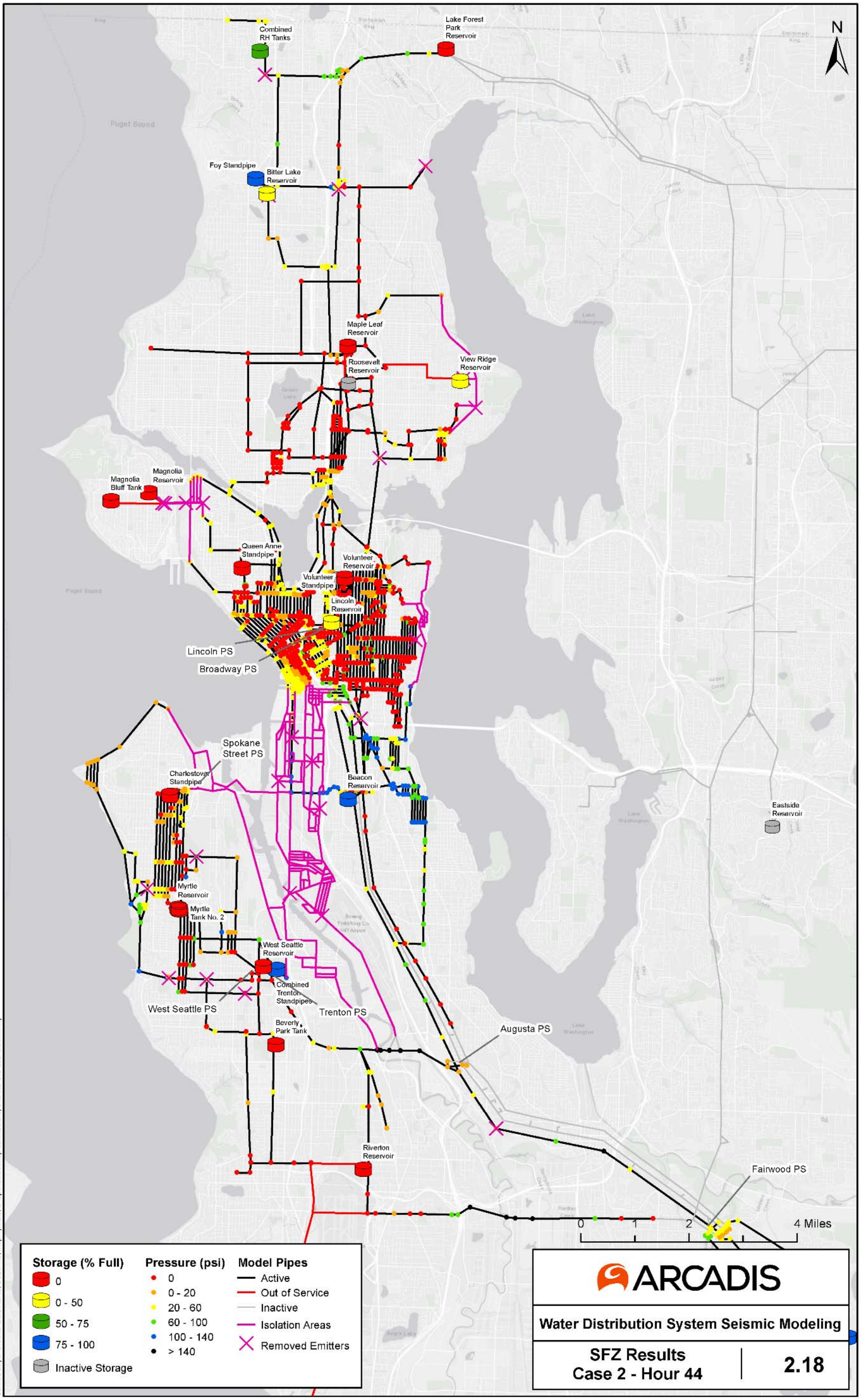

ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 2 - Hour 44

2.18

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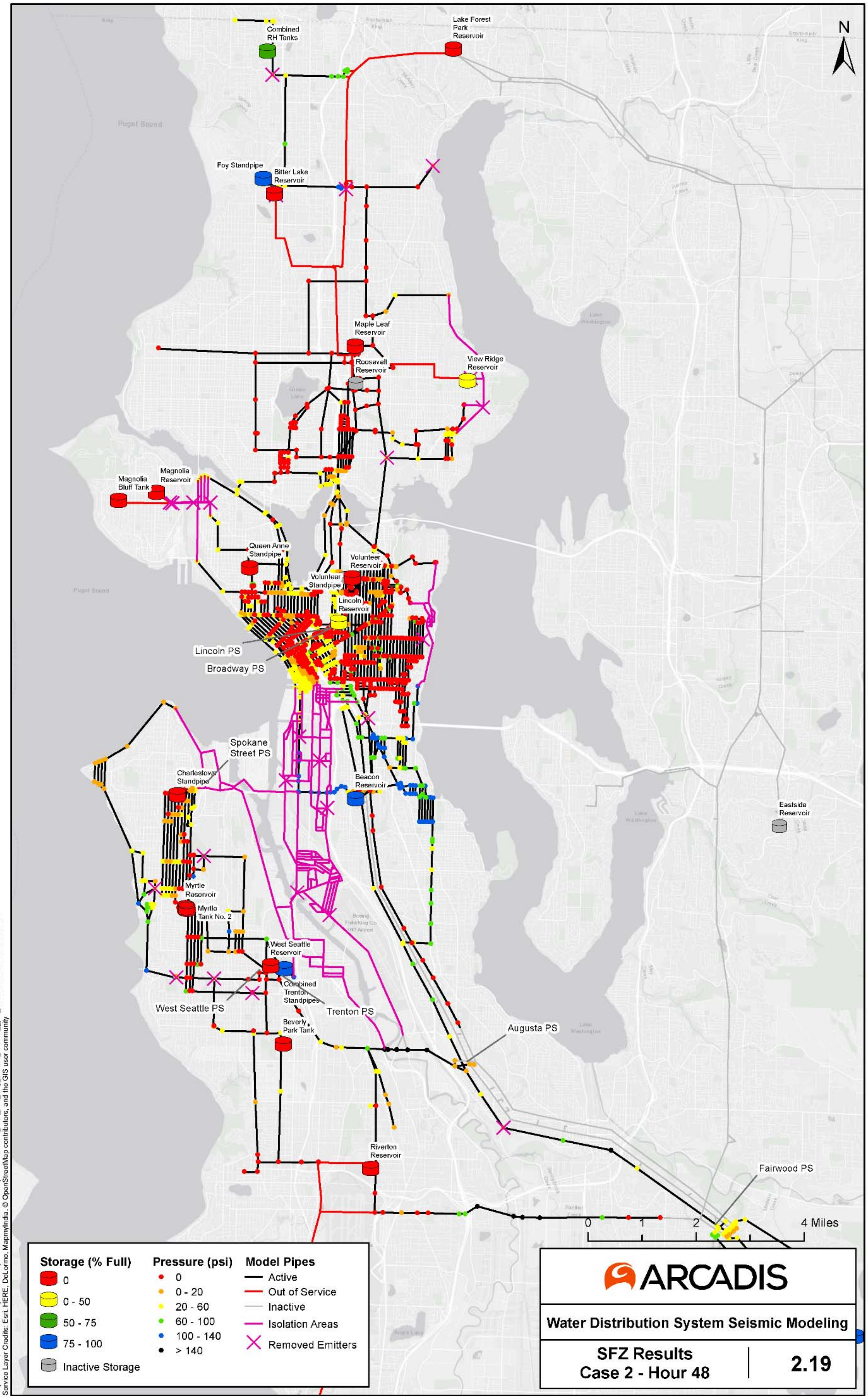

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M7.0 Seattle Fault Zone Case 3 (20 Year Improvements Plus Roosevelt and Volunteer Park Reservoirs Online) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/2/2018

Seattle Fault Seismic Event

Case 3 Same as Case 1

Roosevelt and Volunteer Park Reservoir are Functional

In Service Storage
Eastside Reservoir
Magnolia Bluff Elevated Tank
Magnolia Reservoir
Riverton Heights Reservoir
Roosevelt Reservoir
Volunteer Park Reservoir

In Service Facilities
Lincoln PS
Broadway PS
Spokane Street PS
West Seattle PS

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	149,899	121,992	27,907	90%	340.7
3	149,243	121,992	27,251	90%	316.0
12	128,219	101,479	26,740	86%	248.1
22	91,632	72,635	18,997	66%	181.3
32	59,312	45,916	13,397	45%	125.0
48	18,994	12,378	6,616	17%	80.1

Model Regions Forced Out of Service During Simulation

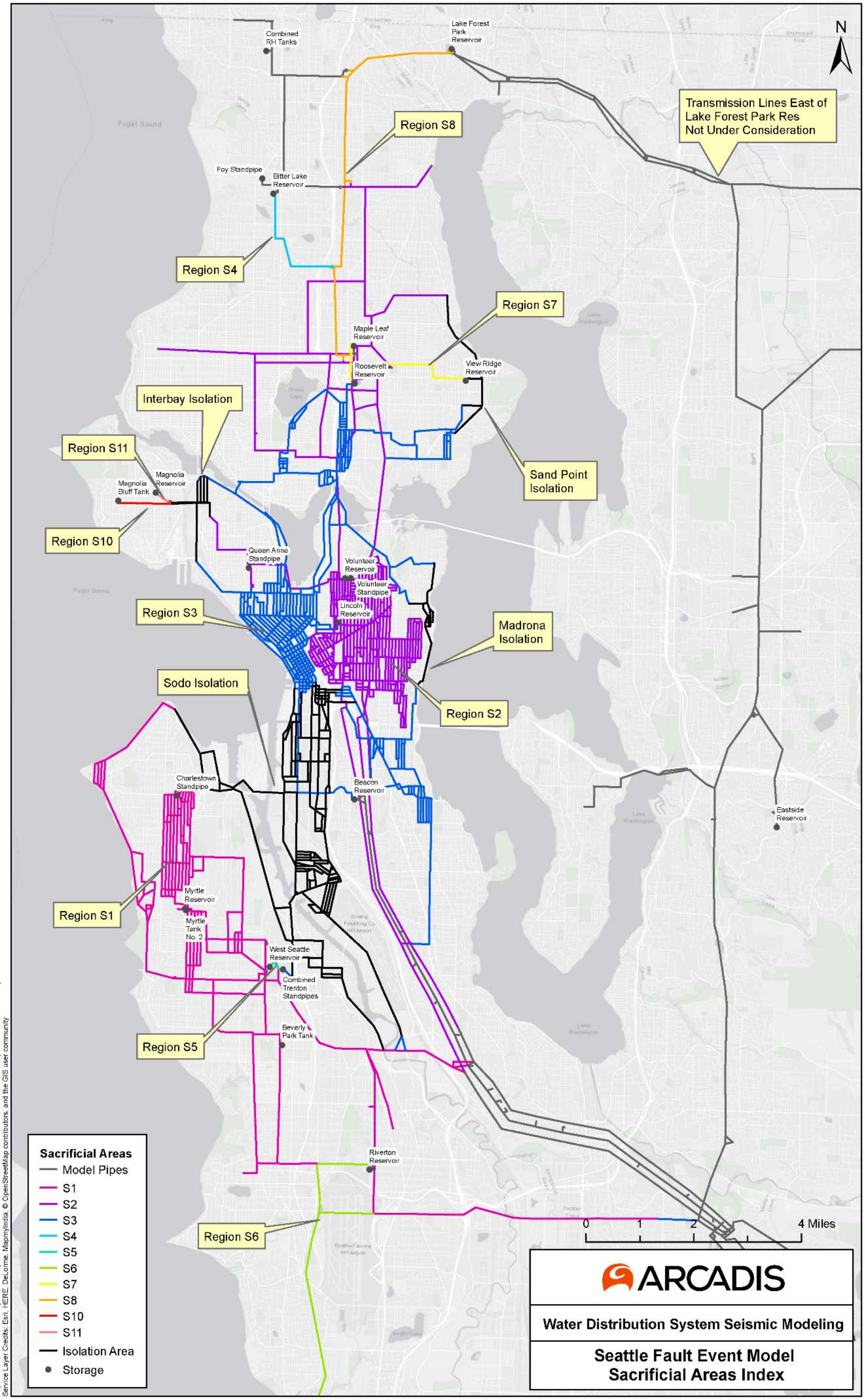
Time	Region
1	S10
16	S6
31	S2
38	S8

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 3.1	Hr 0	Fig. 3.5	Hr 8	Fig. 3.9	Hr 16	Fig. 3.13	Hr 24	Fig. 3.17	Hr 40
Fig. 3.2	Hr 2	Fig. 3.6	Hr 10	Fig. 3.10	Hr 18	Fig. 3.14	Hr 28	Fig. 3.18	Hr 44
Fig. 3.3	Hr 4	Fig. 3.7	Hr 12	Fig. 3.11	Hr 20	Fig. 3.15	Hr 32	Fig. 3.19	Hr 48
Fig. 3.4	Hr 6	Fig. 3.8	Hr 14	Fig. 3.12	Hr 22	Fig. 3.16	Hr 36		



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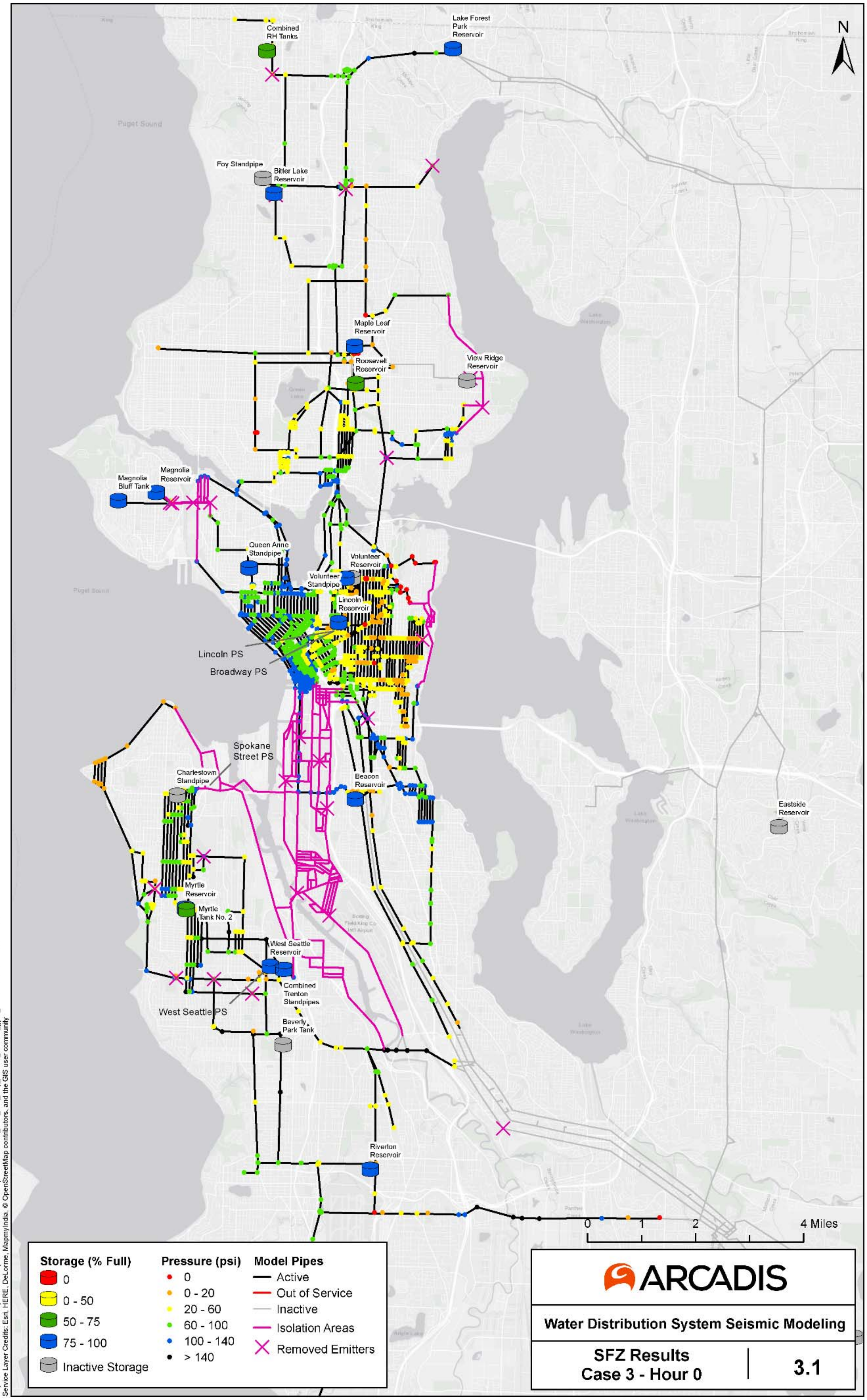

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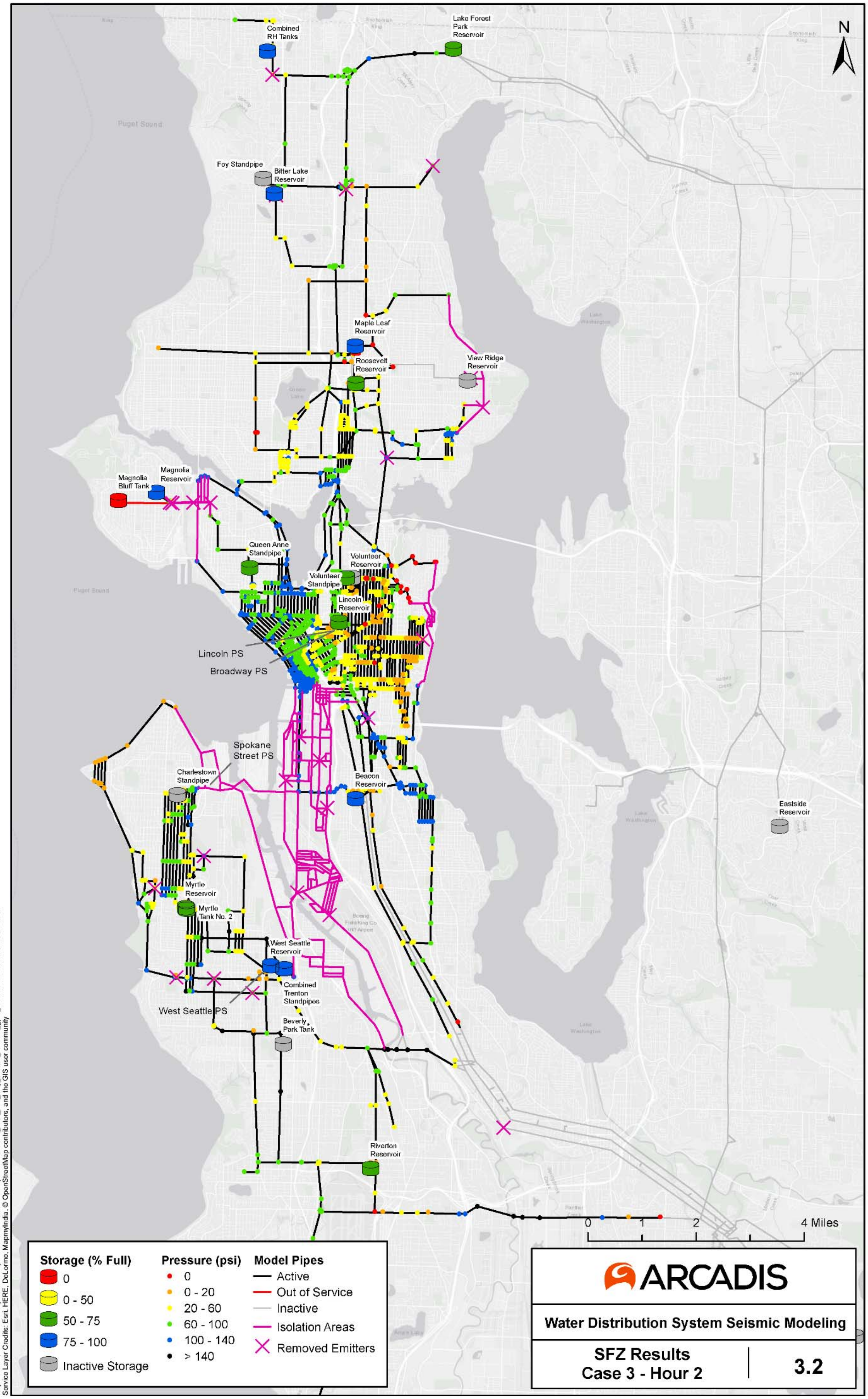

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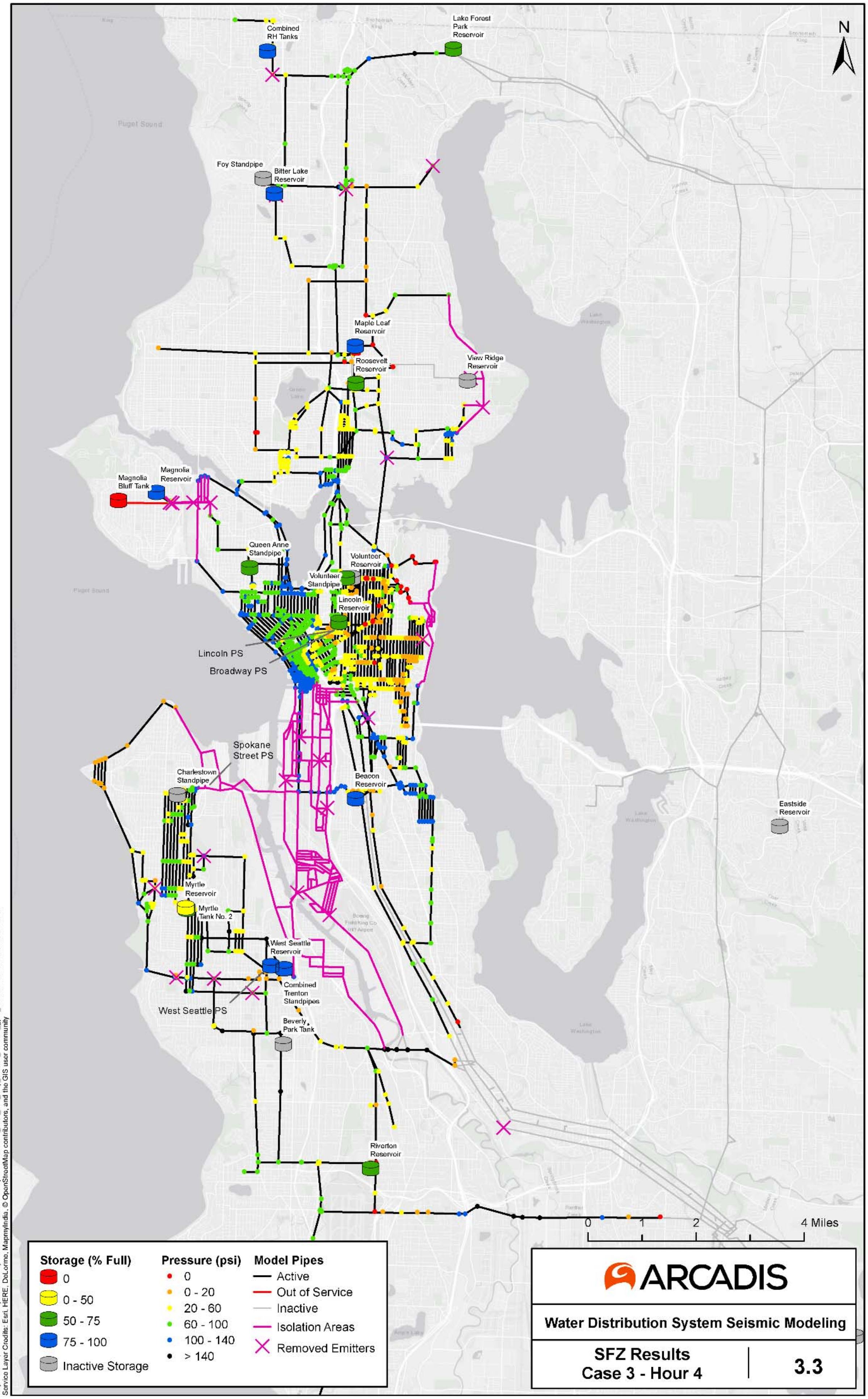

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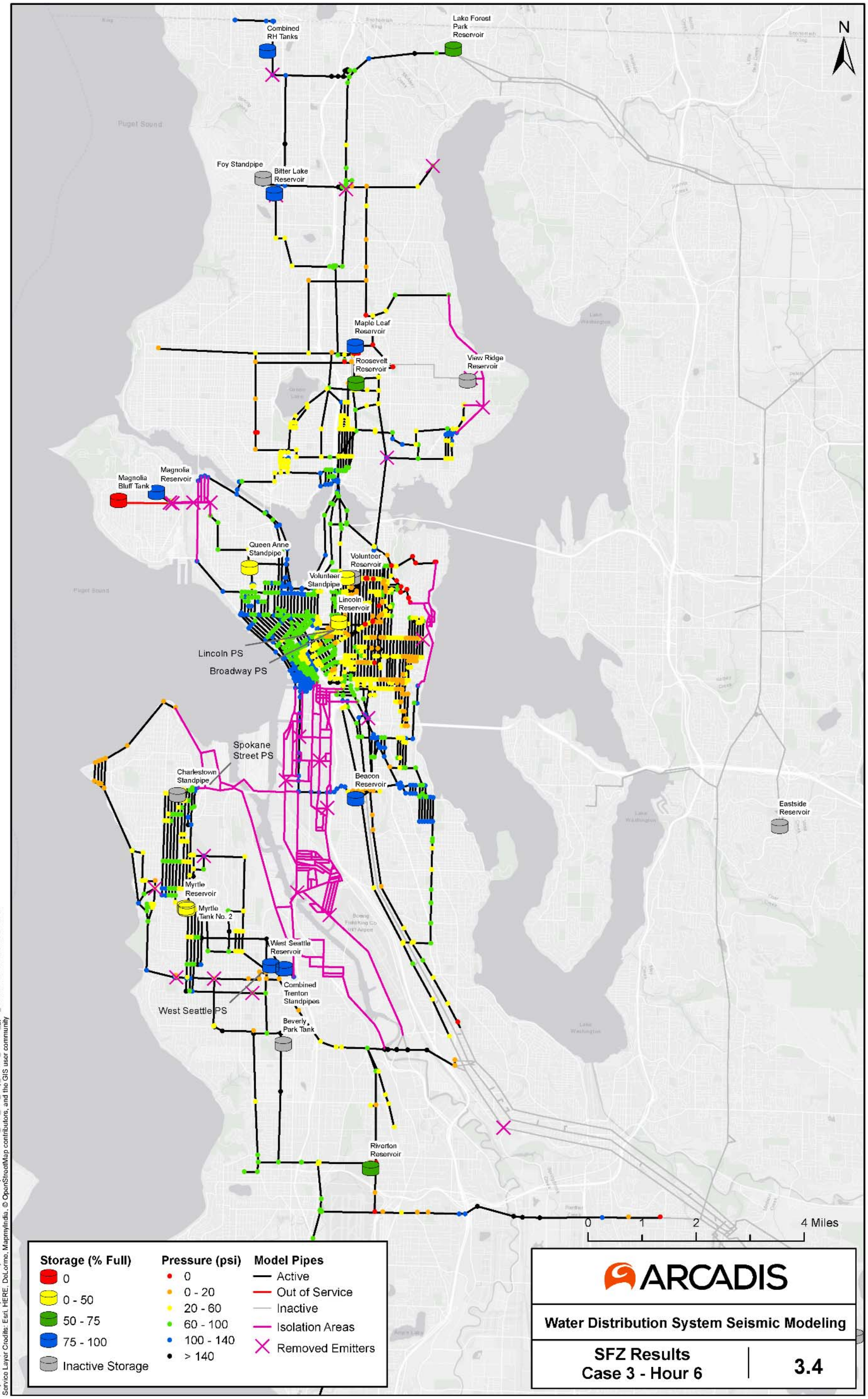

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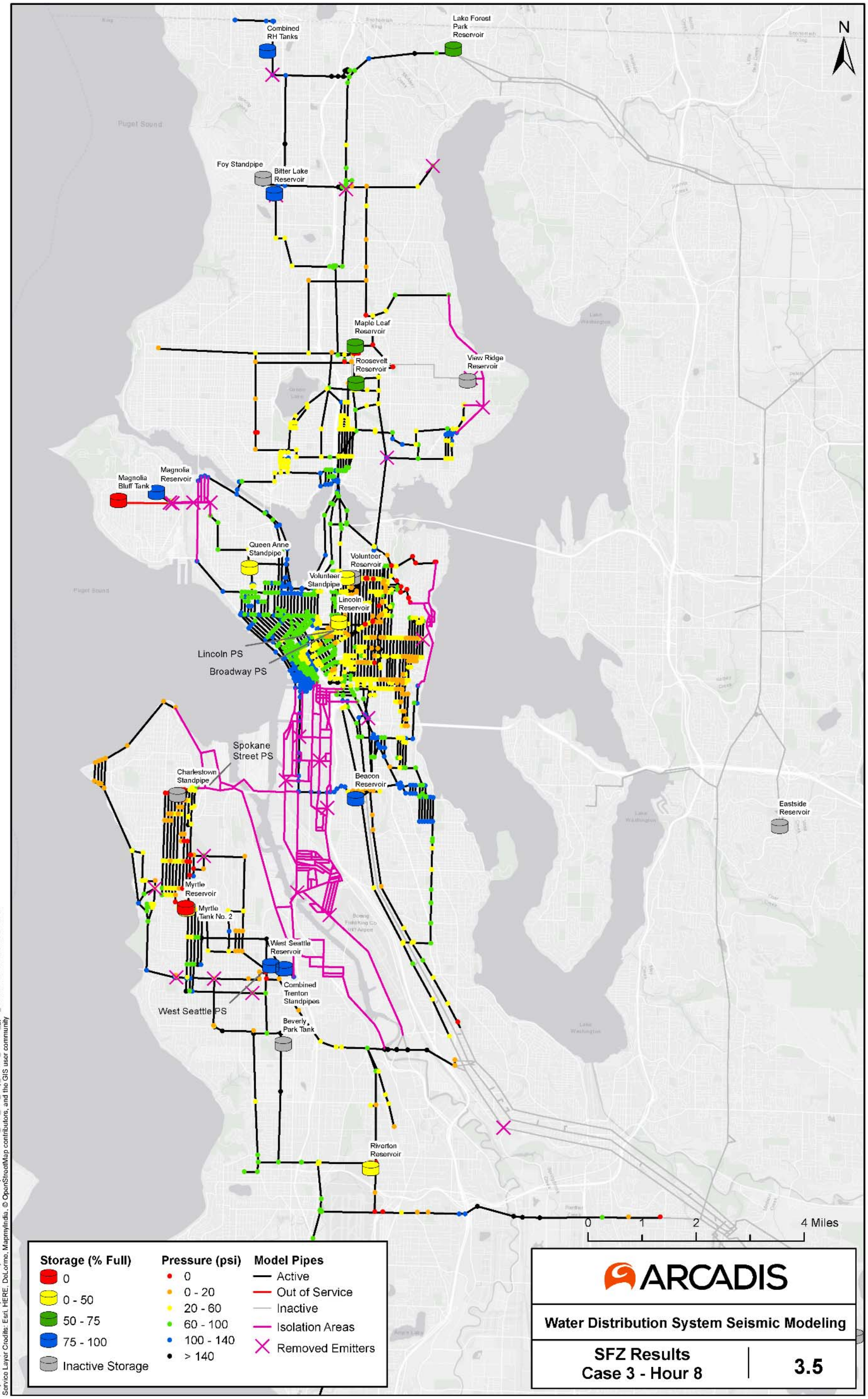

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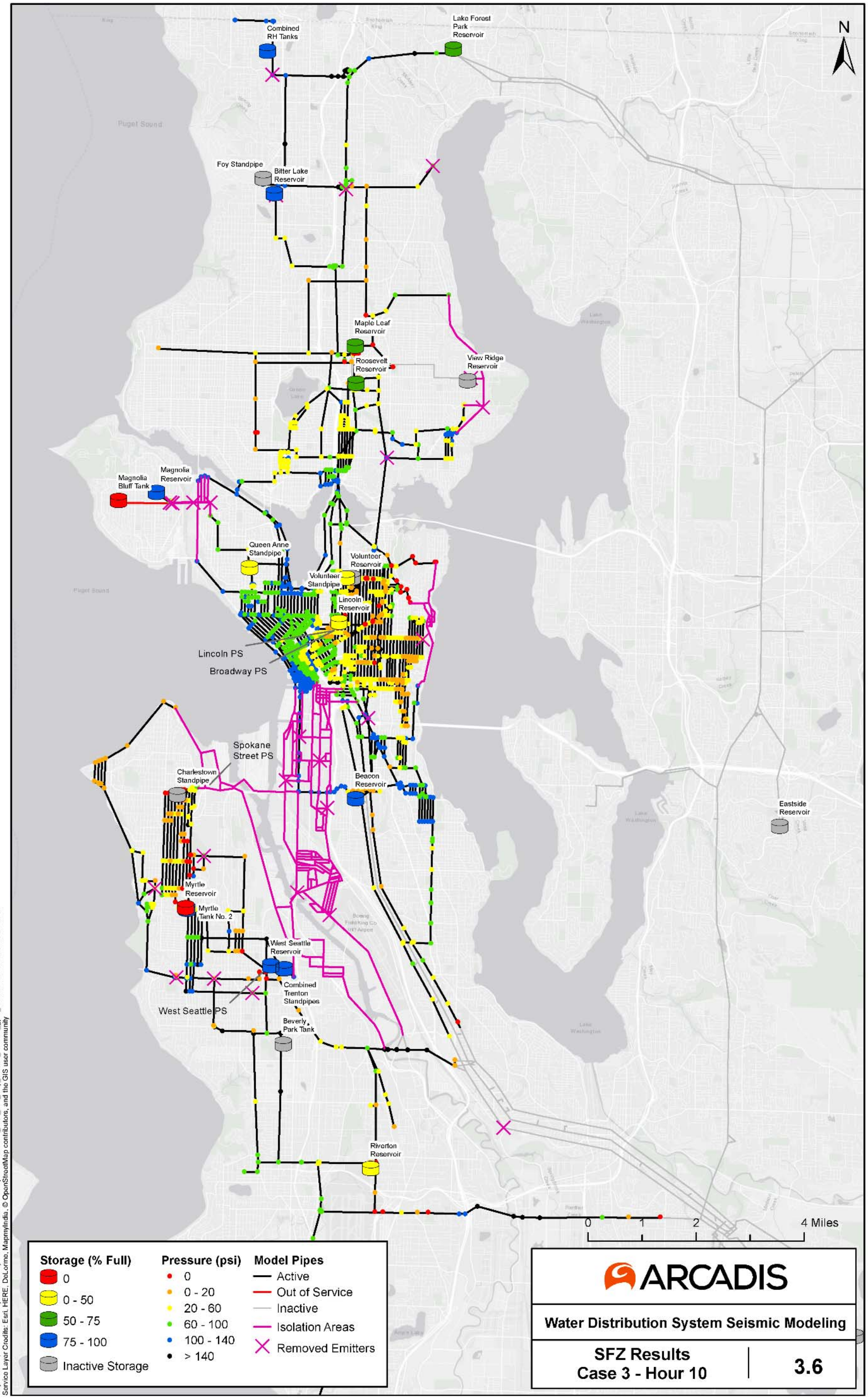

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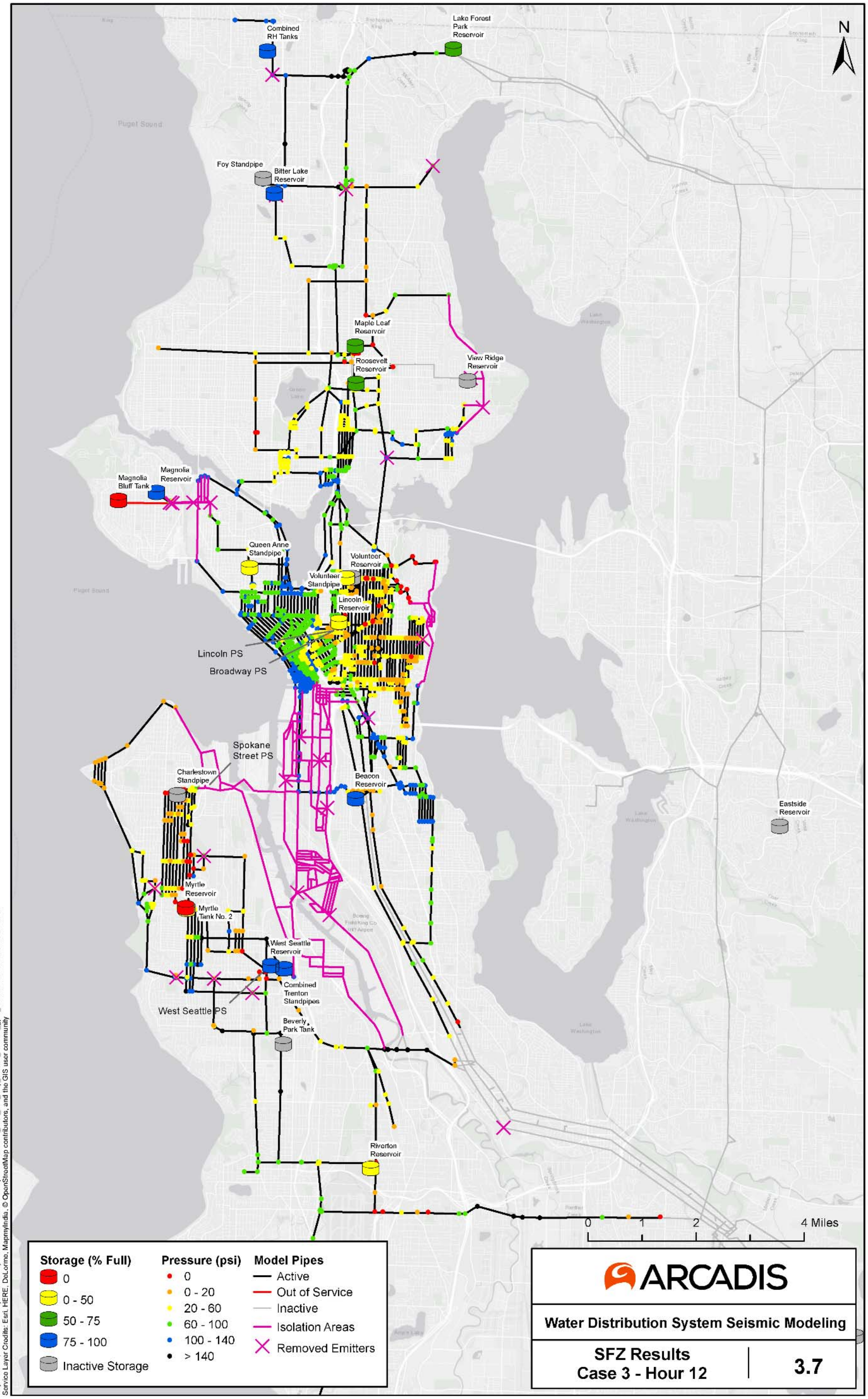

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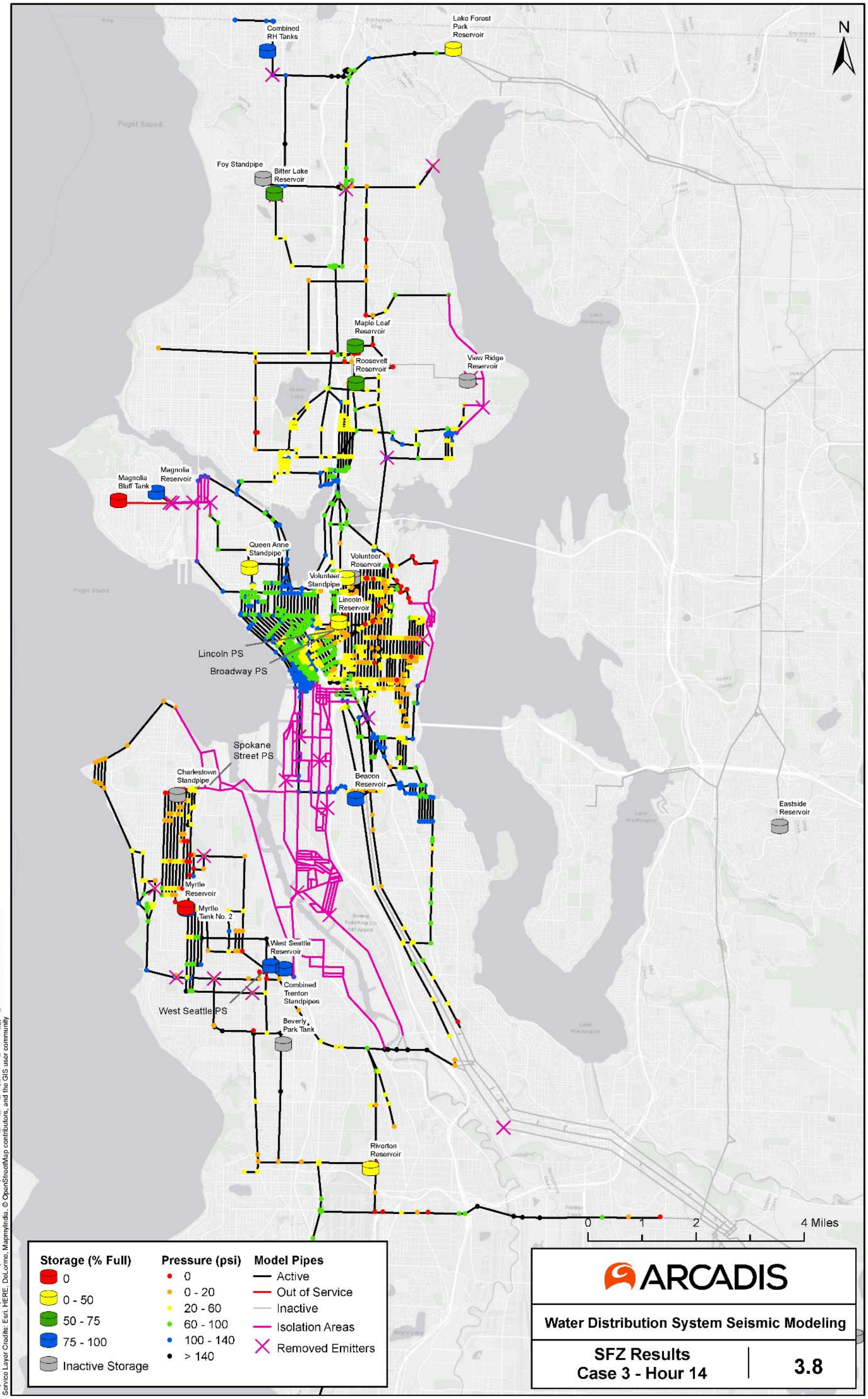

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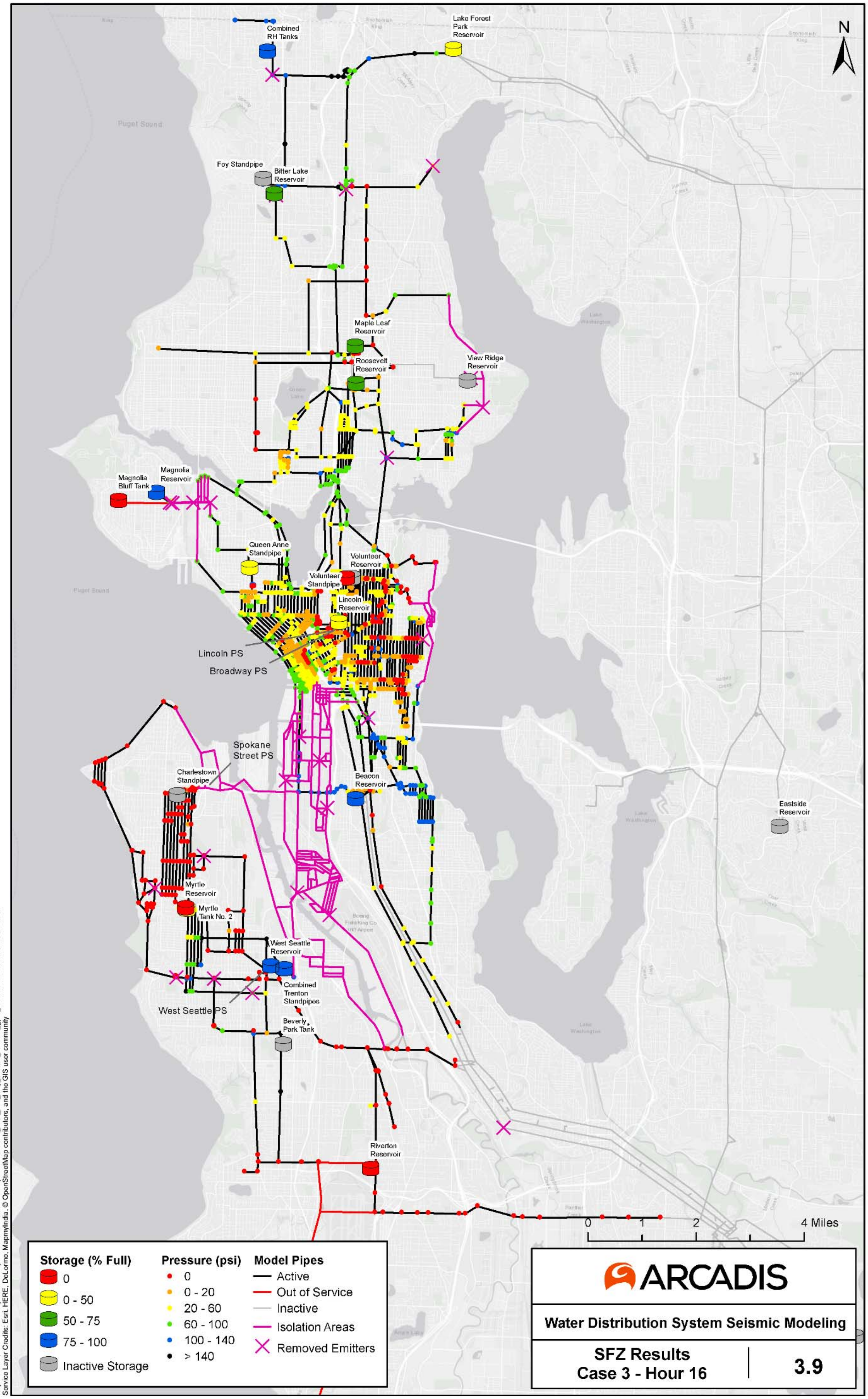

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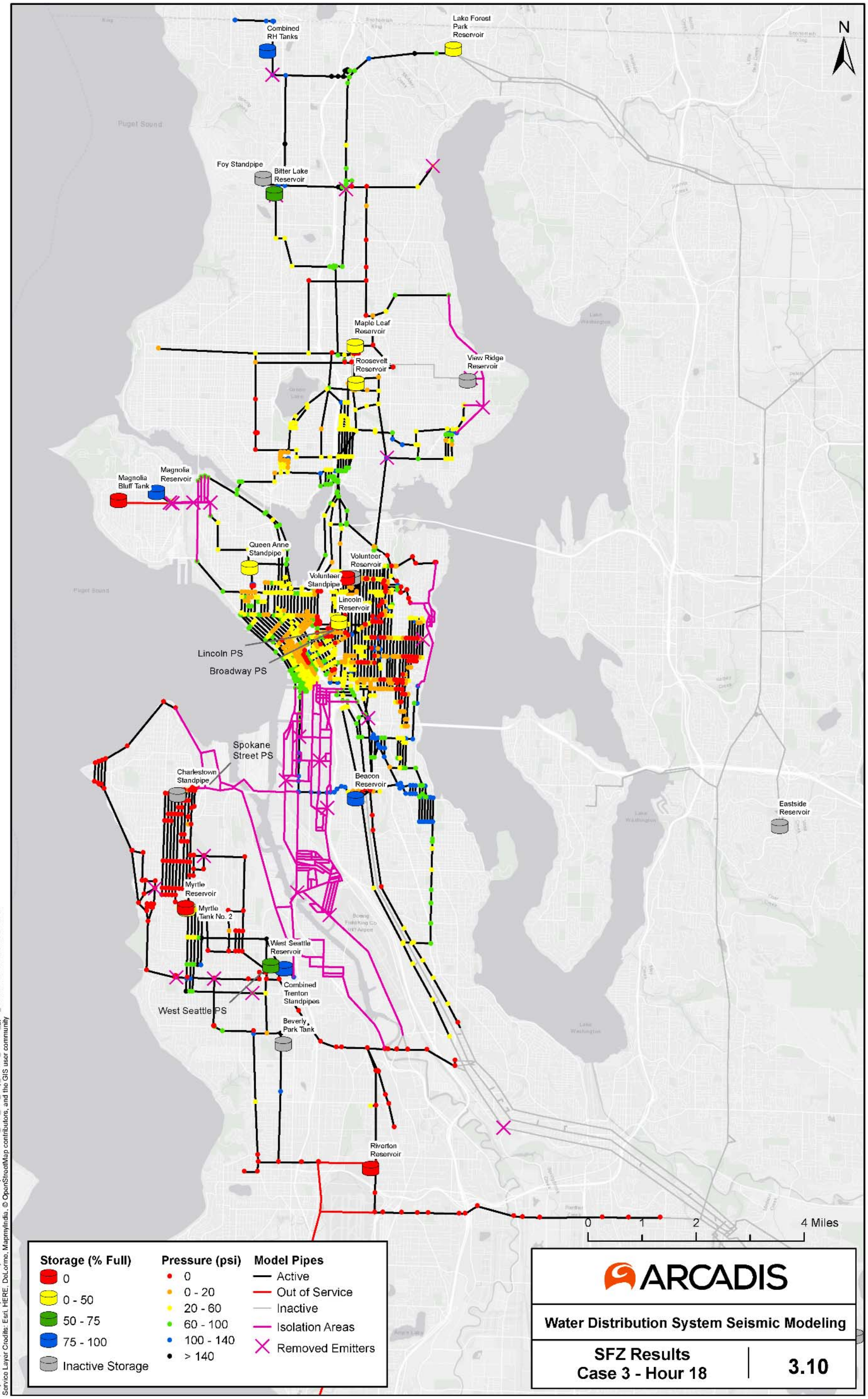

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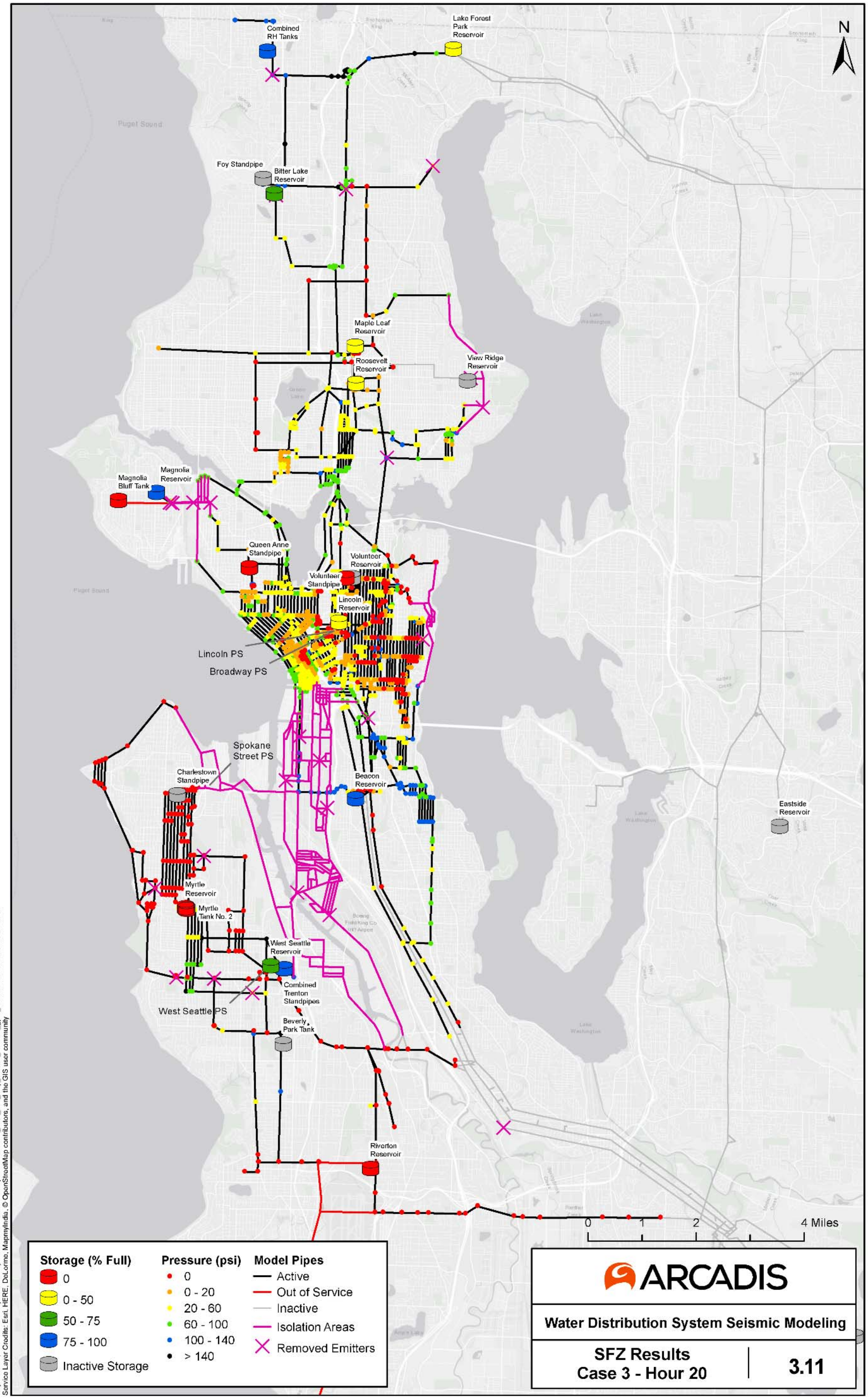

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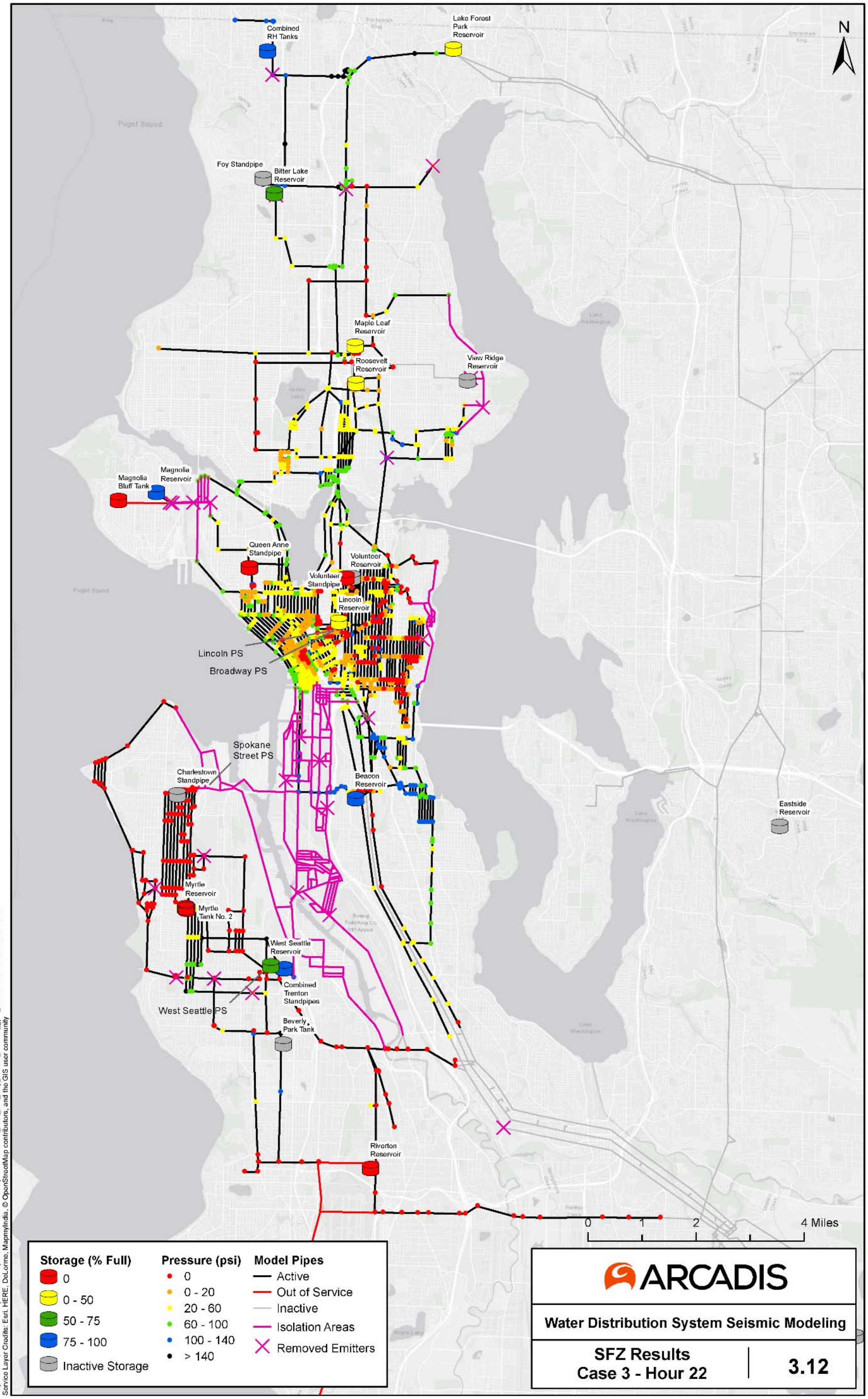

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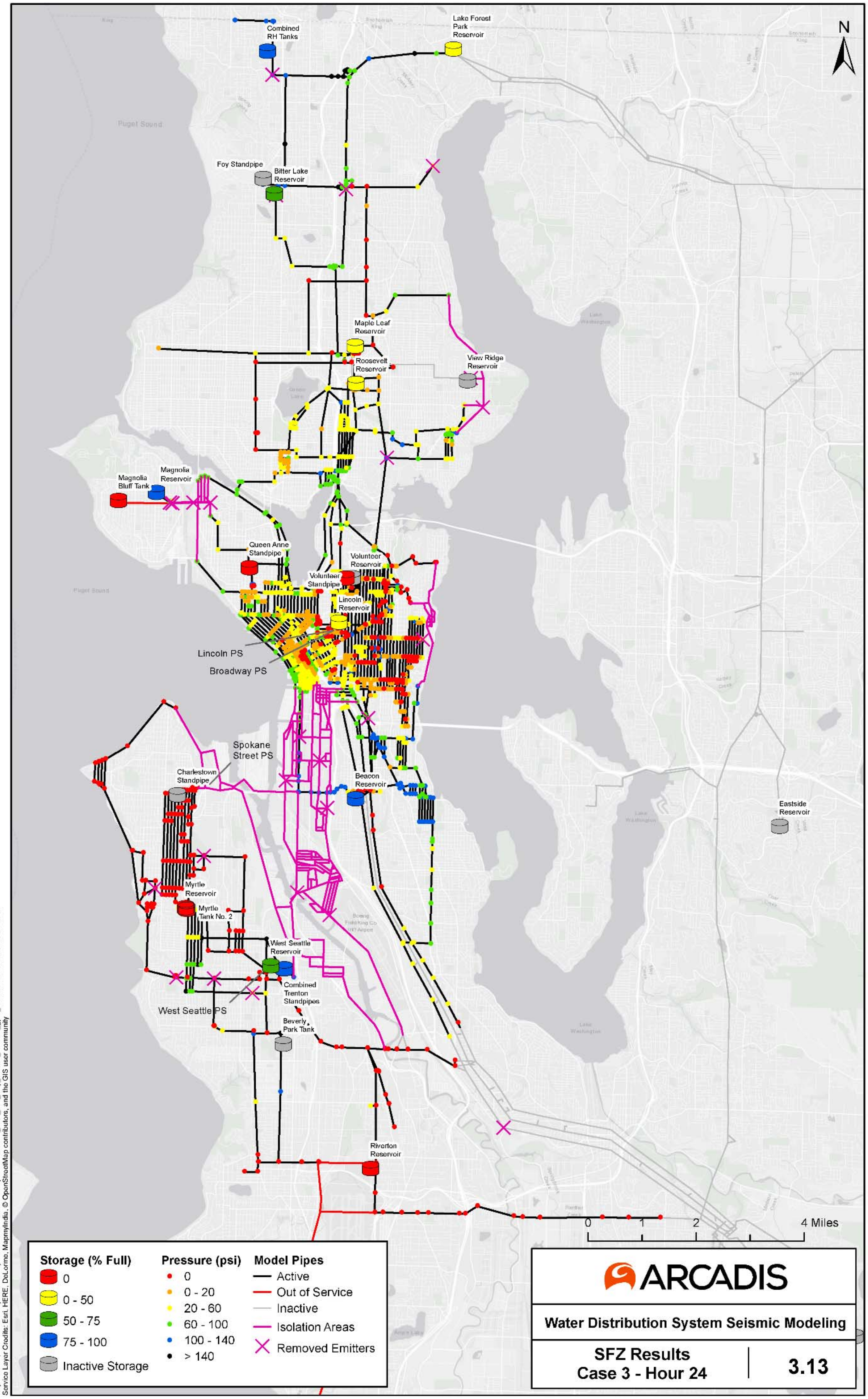

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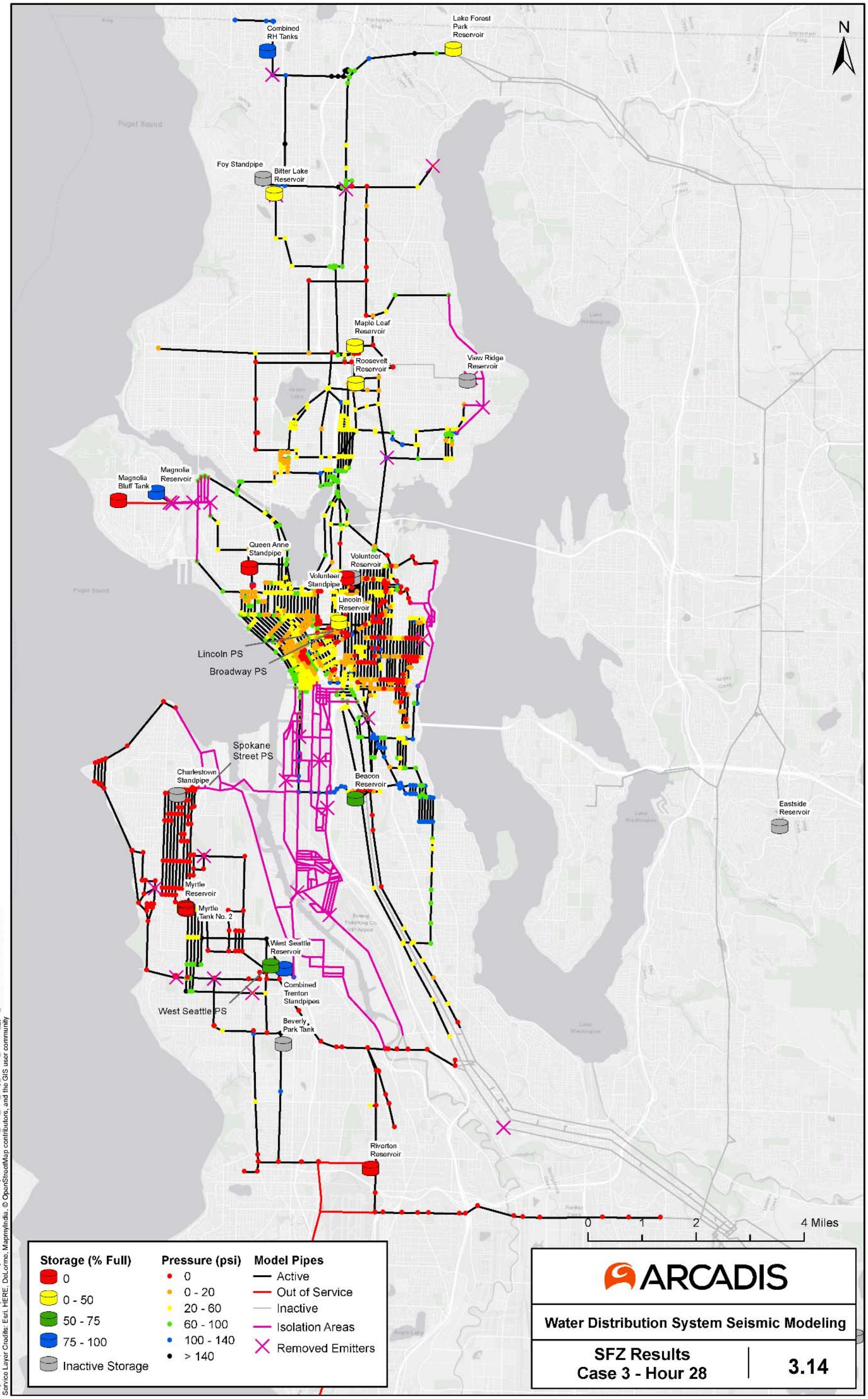

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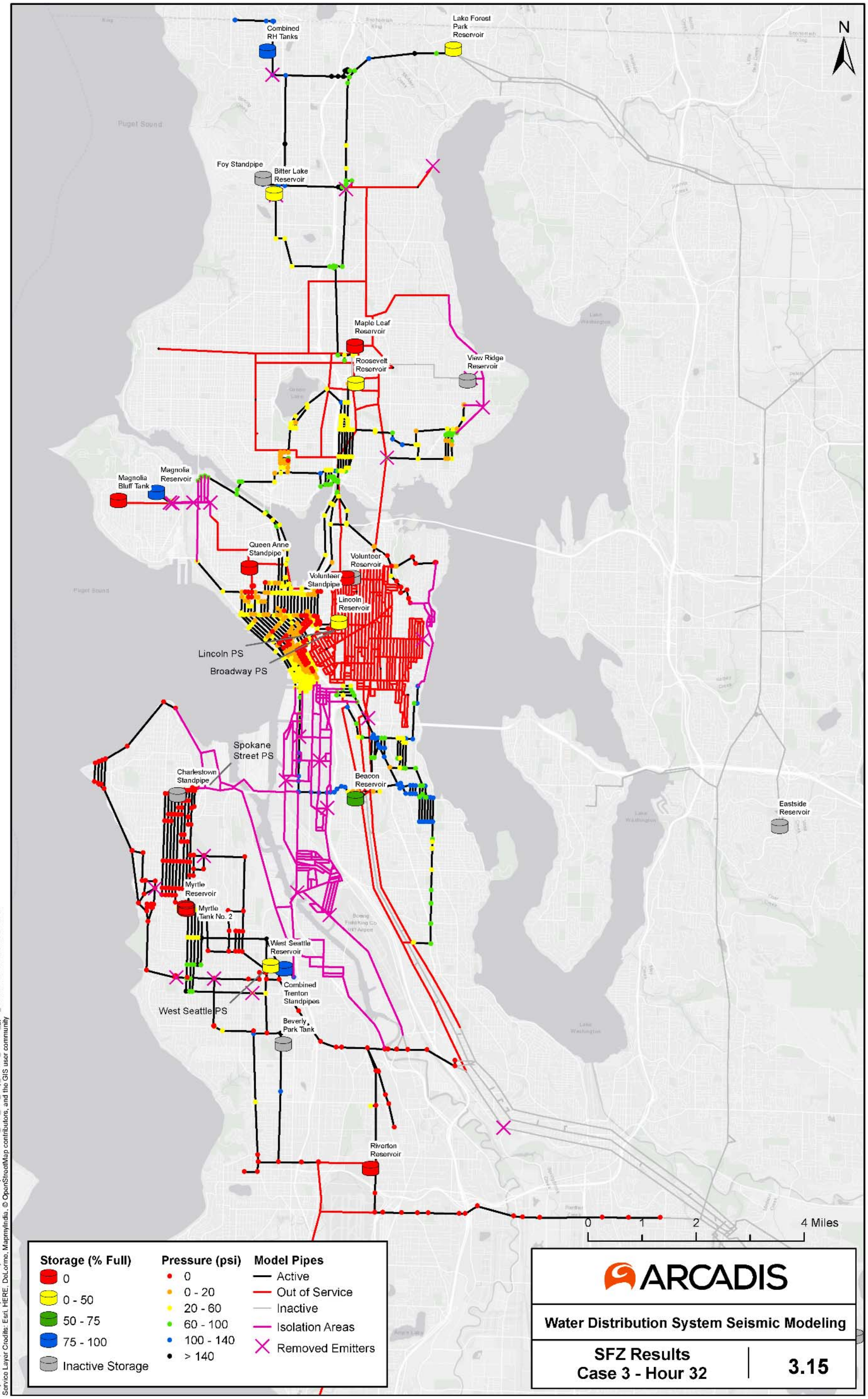

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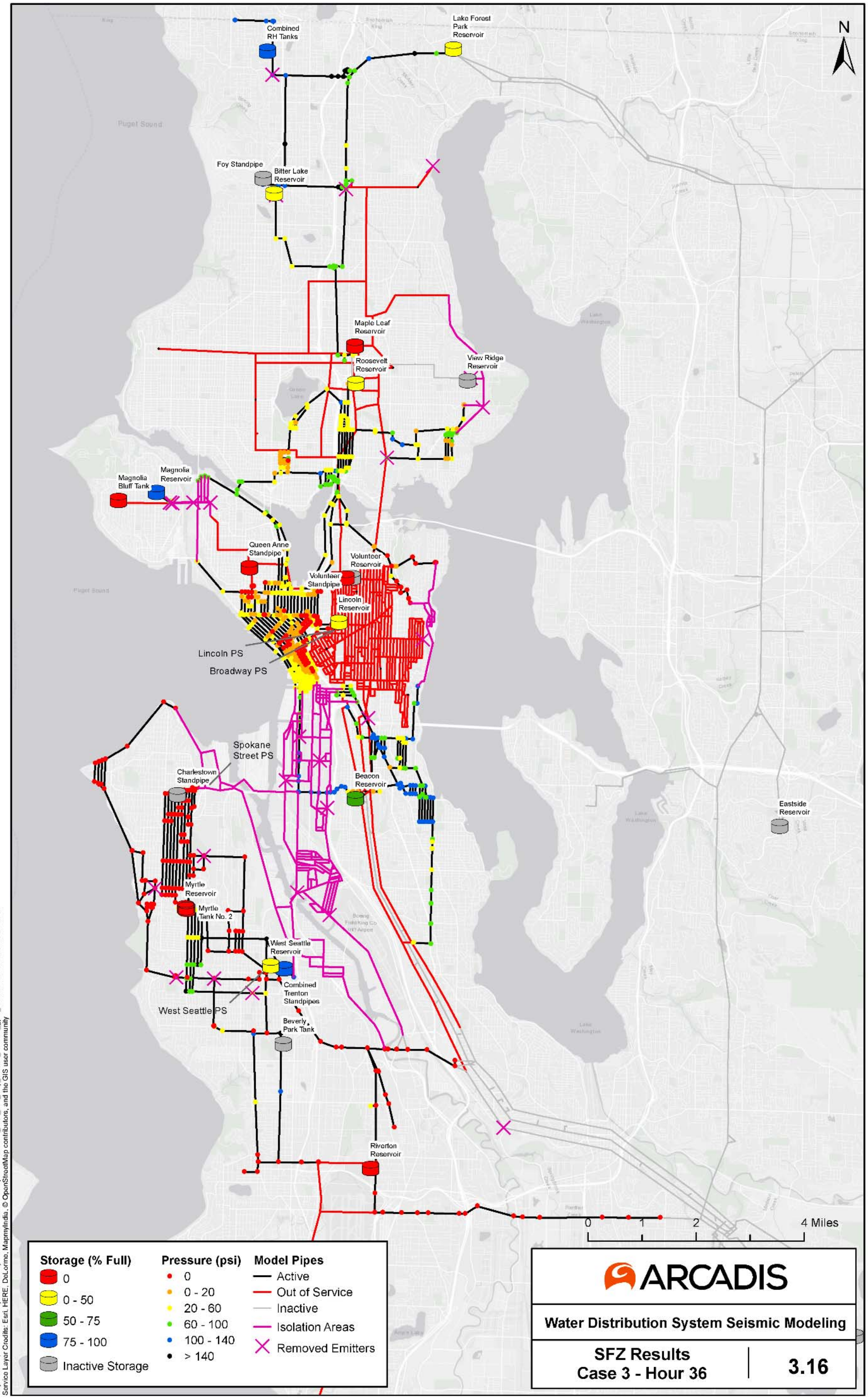

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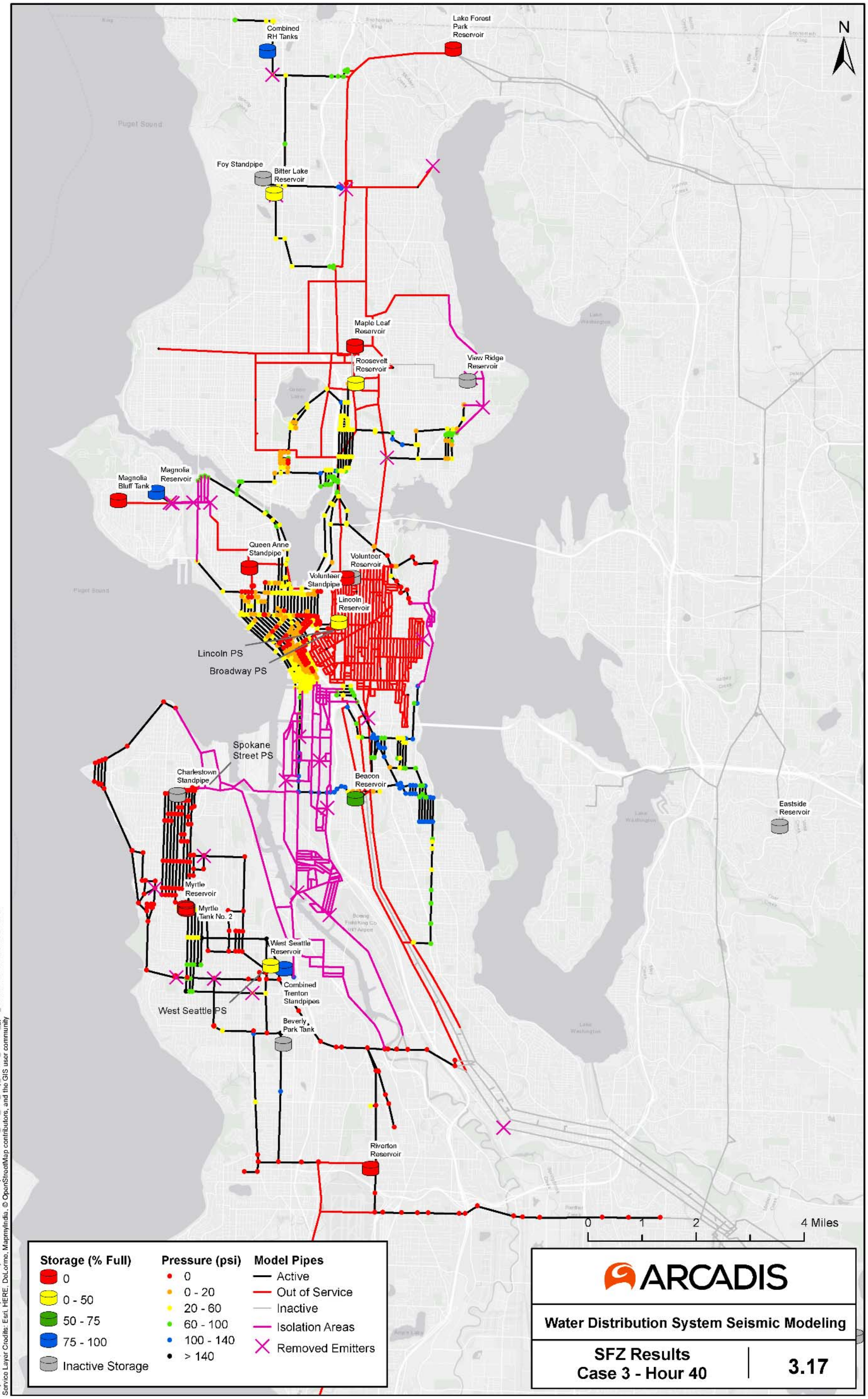

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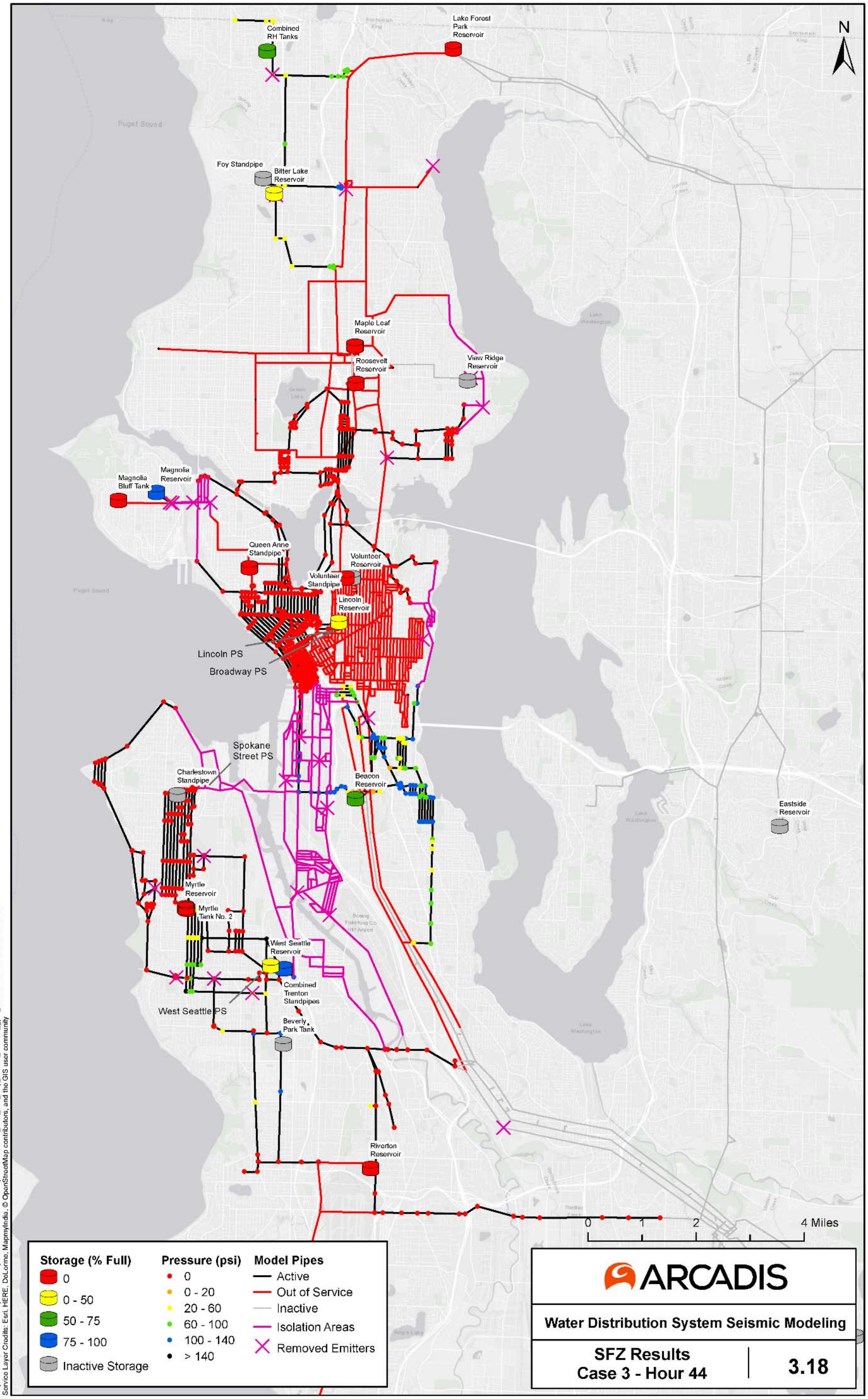

Water Distribution System Seismic Modeling

SFZ Results
Case 3 - Hour 44

3.18

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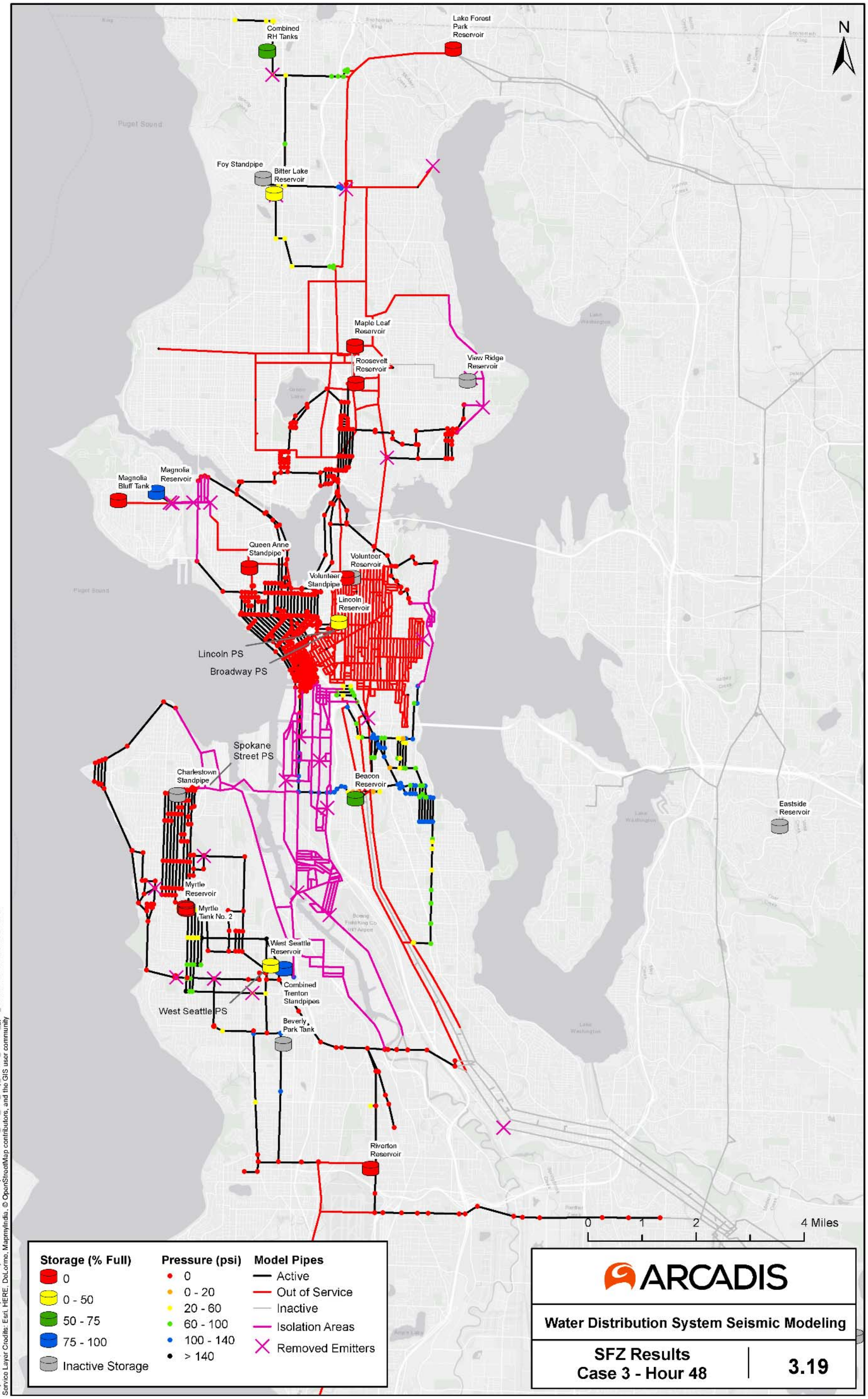

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Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

M7.0 Seattle Fault Zone Case 4 (50 Year Improvements Plus Roosevelt and Volunteer Park Reservoirs Online) Hydraulic Modeling Results

ARCADIS | Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/2/2018

Seattle Fault Seismic Event

Case 4 Same as Case 2

Roosevelt and Volunteer Park Reservoir are Functional

In Service Storage
Eastside Reservoir
Magnolia Bluff Elevated Tank
Magnolia Reservoir
Riverton Heights Reservoir
Beverly Park Elevated Tank
Charlestown Standpipe
Foy Standpipe
View Ridge Reservoir
Volunteer Park Standpipe
Roosevelt Reservoir
Volunteer Park Reservoir

In Service Facilities
Lincoln PS
Broadway PS
Spokane Street PS
West Seattle PS
Trenton PS
Augusta PS
Fairwood PS

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	172,157	141,232	30,926	92%	347.8
3	159,710	128,809	30,901	91%	325.8
12	150,350	119,736	30,614	89%	266.9
22	138,135	108,736	29,399	86%	205.1
32	129,636	102,448	27,187	82%	149.7
48	68,790	48,462	20,328	62%	91.5

Model Regions Forced Out of Service During Simulation

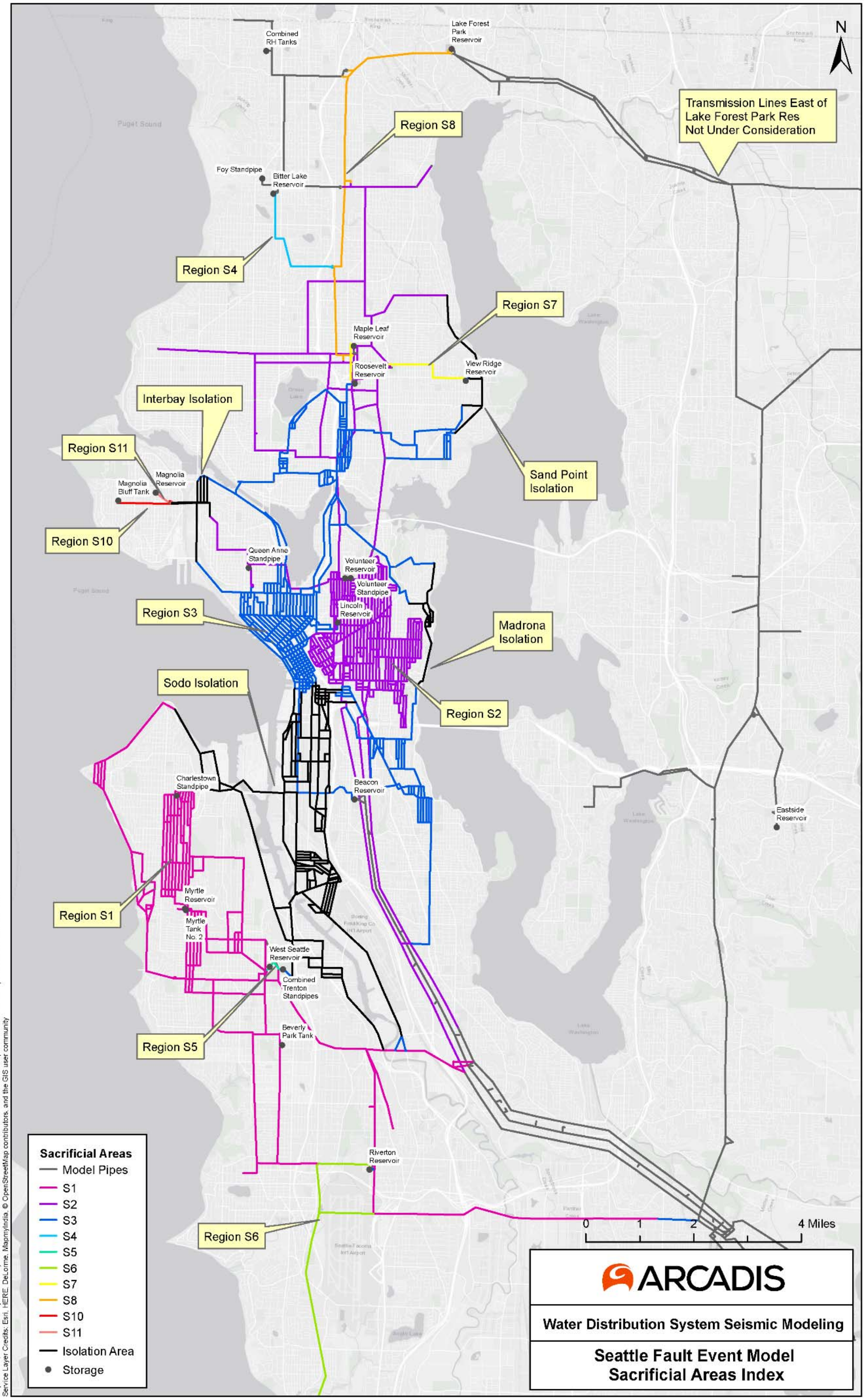
Time	Region
13	S7
24	S11
27	S6
47	S4
47	S8

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 4.1	Hr 0	Fig. 4.5	Hr 8	Fig. 4.9	Hr 16	Fig. 4.13	Hr 24	Fig. 4.17	Hr 40
Fig. 4.2	Hr 2	Fig. 4.6	Hr 10	Fig. 4.10	Hr 18	Fig. 4.14	Hr 28	Fig. 4.18	Hr 44
Fig. 4.3	Hr 4	Fig. 4.7	Hr 12	Fig. 4.11	Hr 20	Fig. 4.15	Hr 32	Fig. 4.19	Hr 48
Fig. 4.4	Hr 6	Fig. 4.8	Hr 14	Fig. 4.12	Hr 22	Fig. 4.16	Hr 36		



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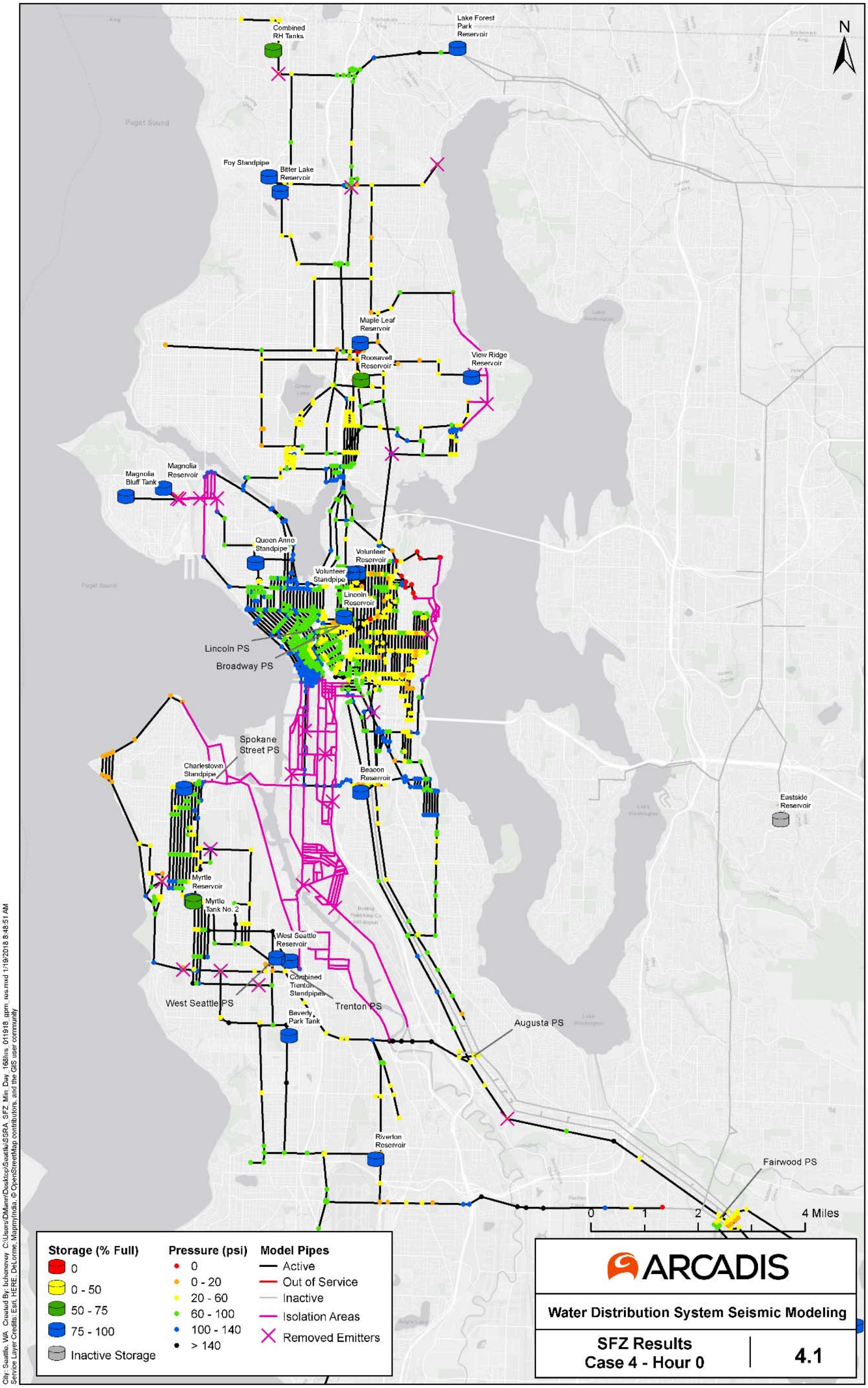

N
Combined RH Tanks
Lake Forest Park Reservoir
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Lincoln PS
Broadway PS
Spokane Street PS
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
West Seattle PS
Trenton PS
Beverly Park Tank
Augusta PS
Riverton Reservoir
Fairwood PS
0
1
2
4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
Removed Emitters
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 4 - Hour 0
4.1
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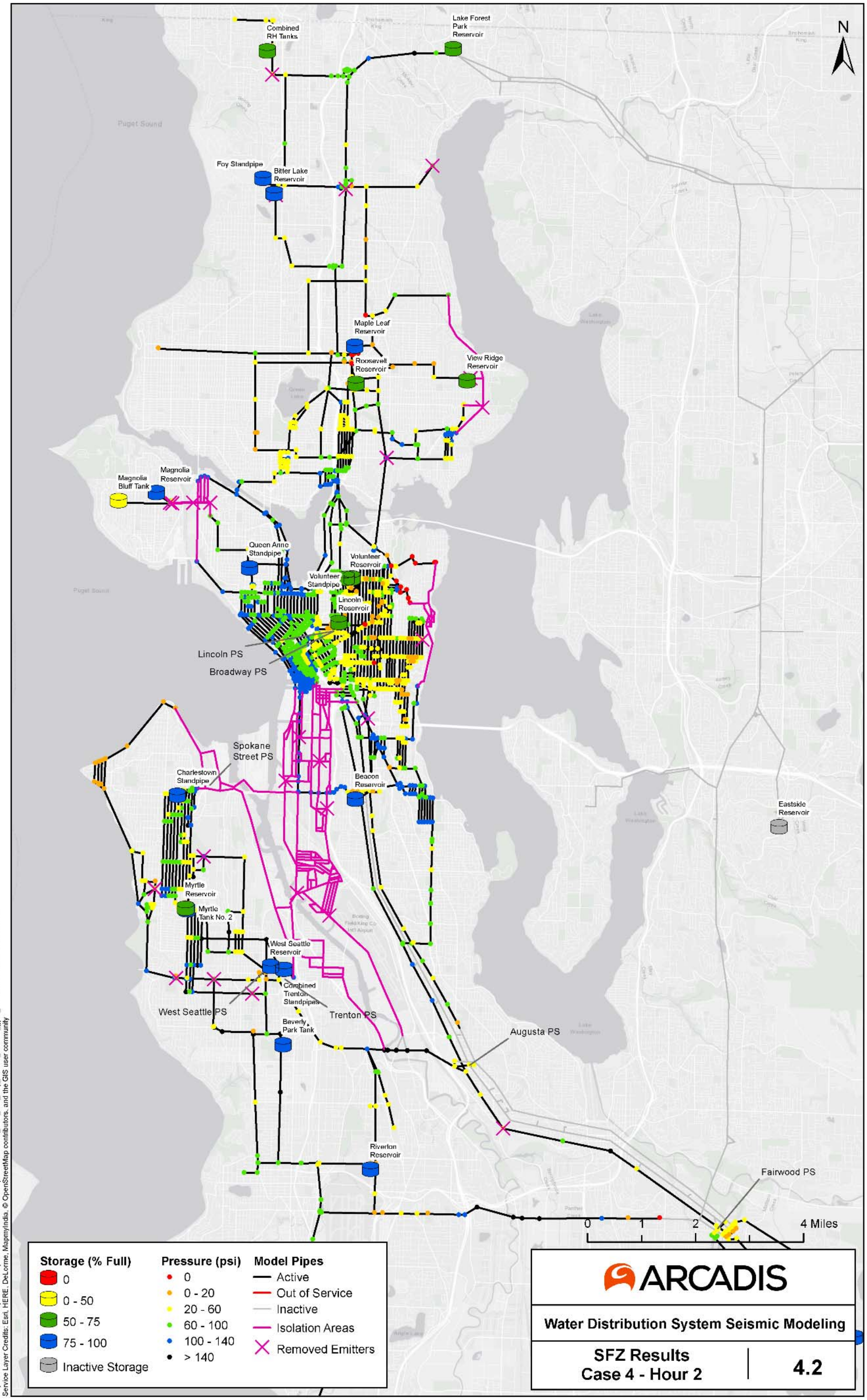

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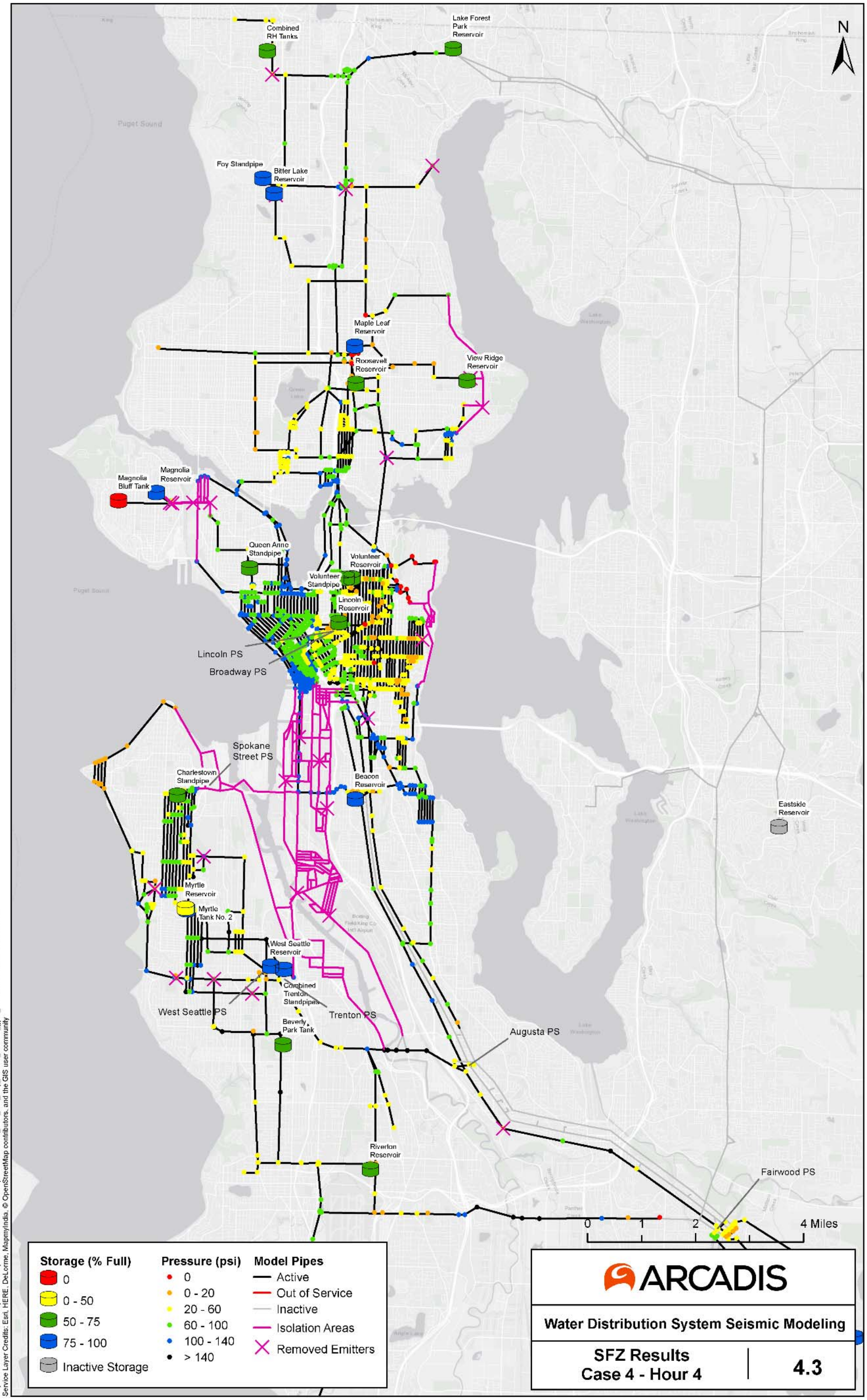

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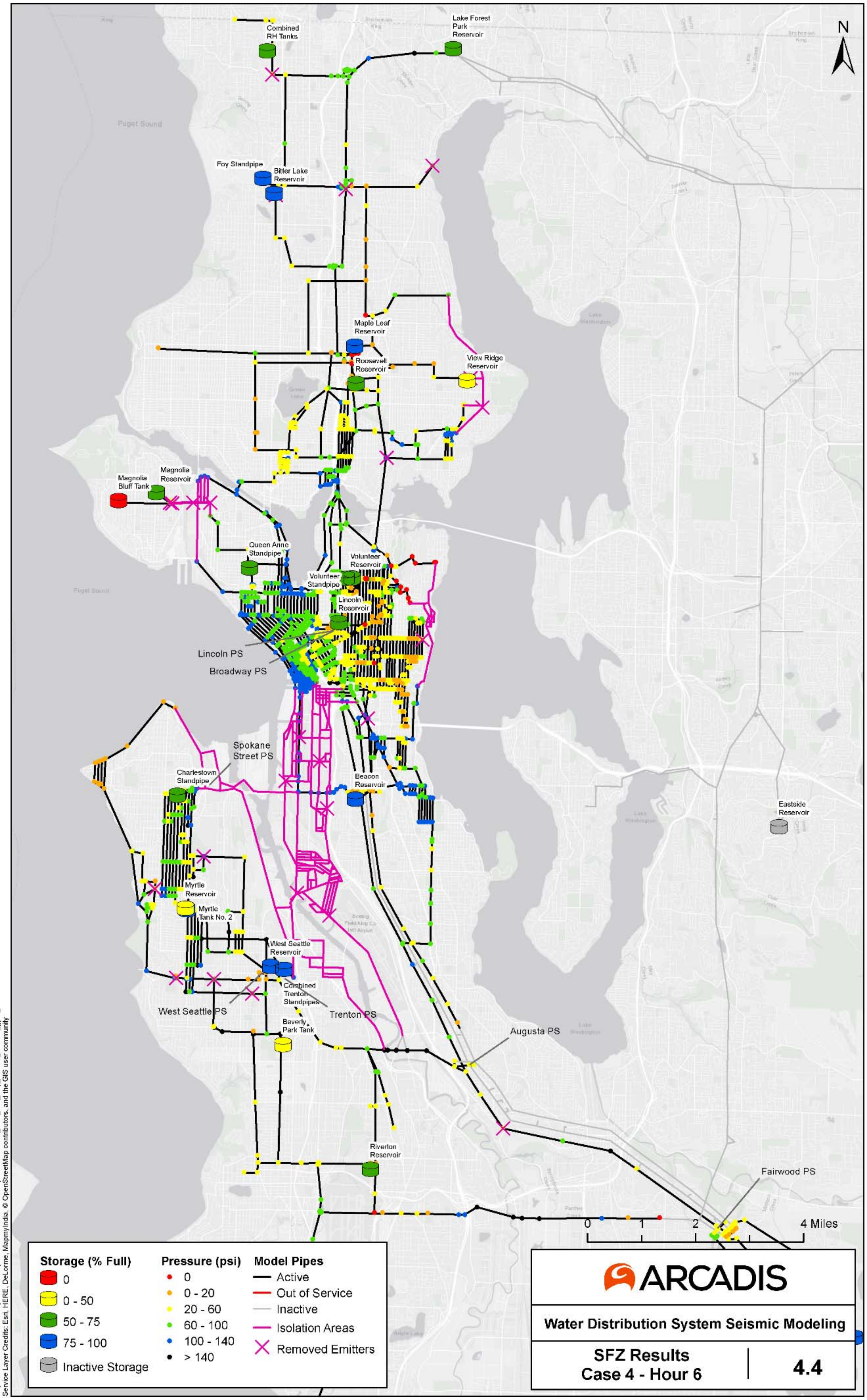

Water Distribution System Seismic Modeling

SFZ Results
Case 4 - Hour 6

4.4

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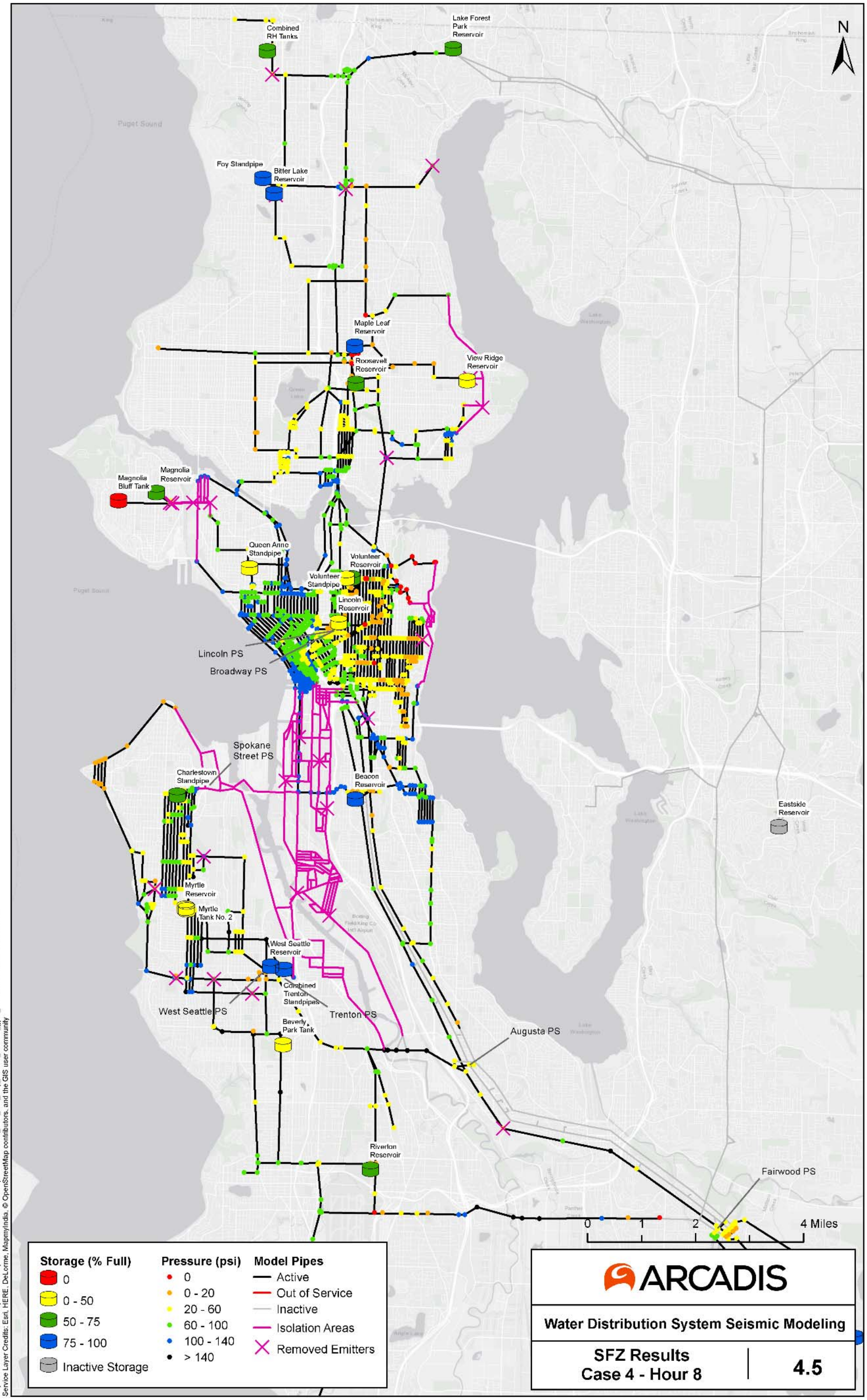

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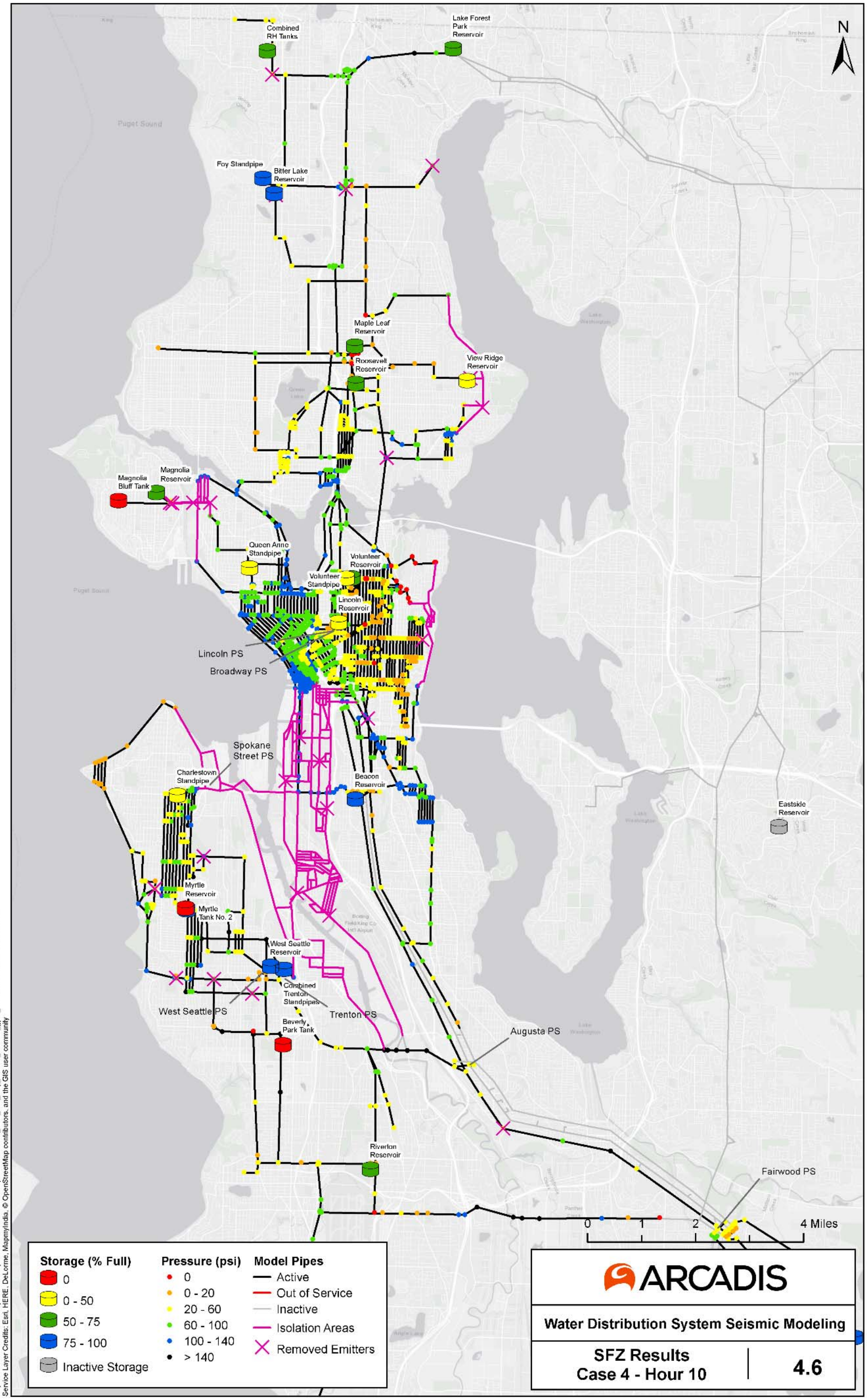

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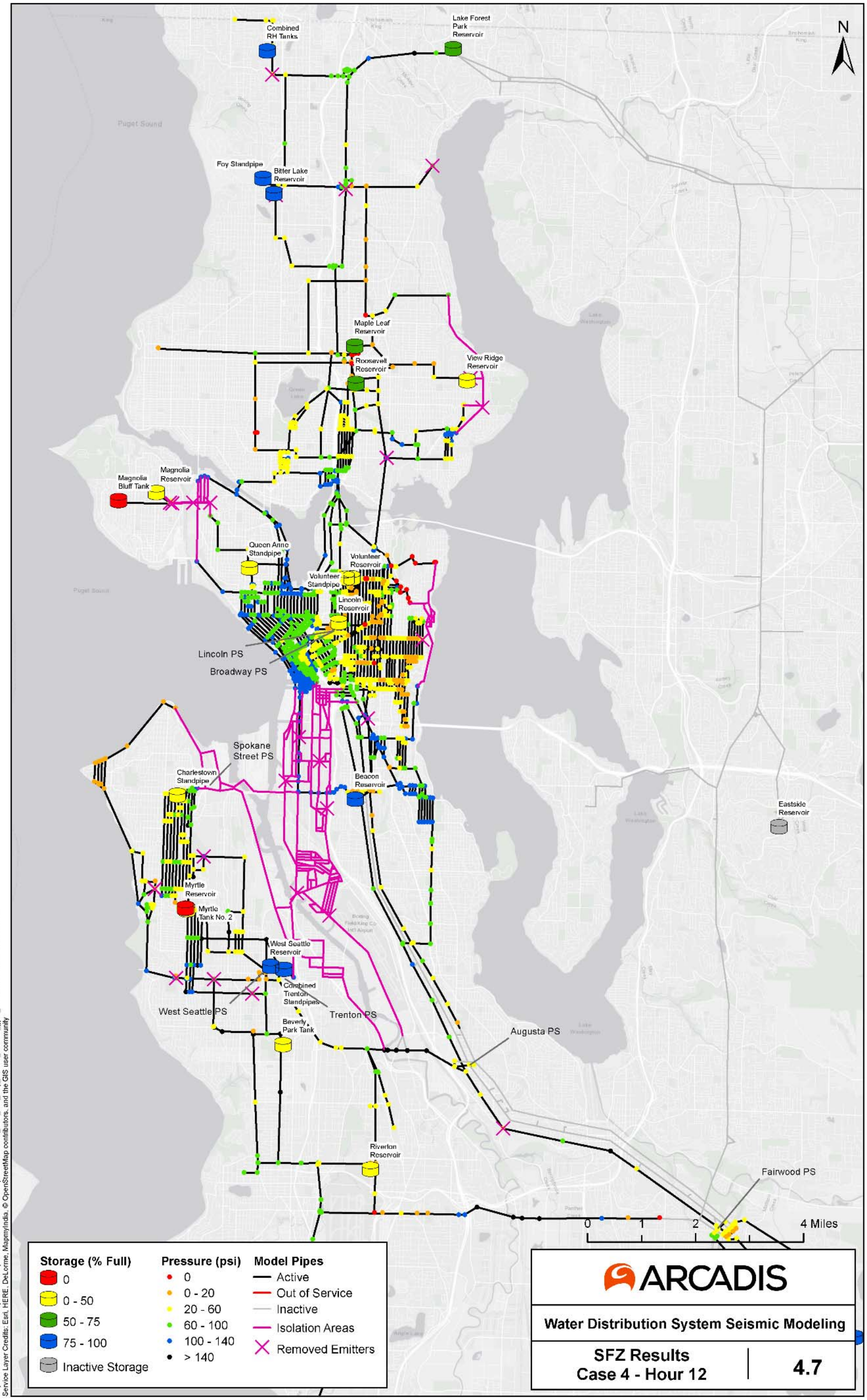

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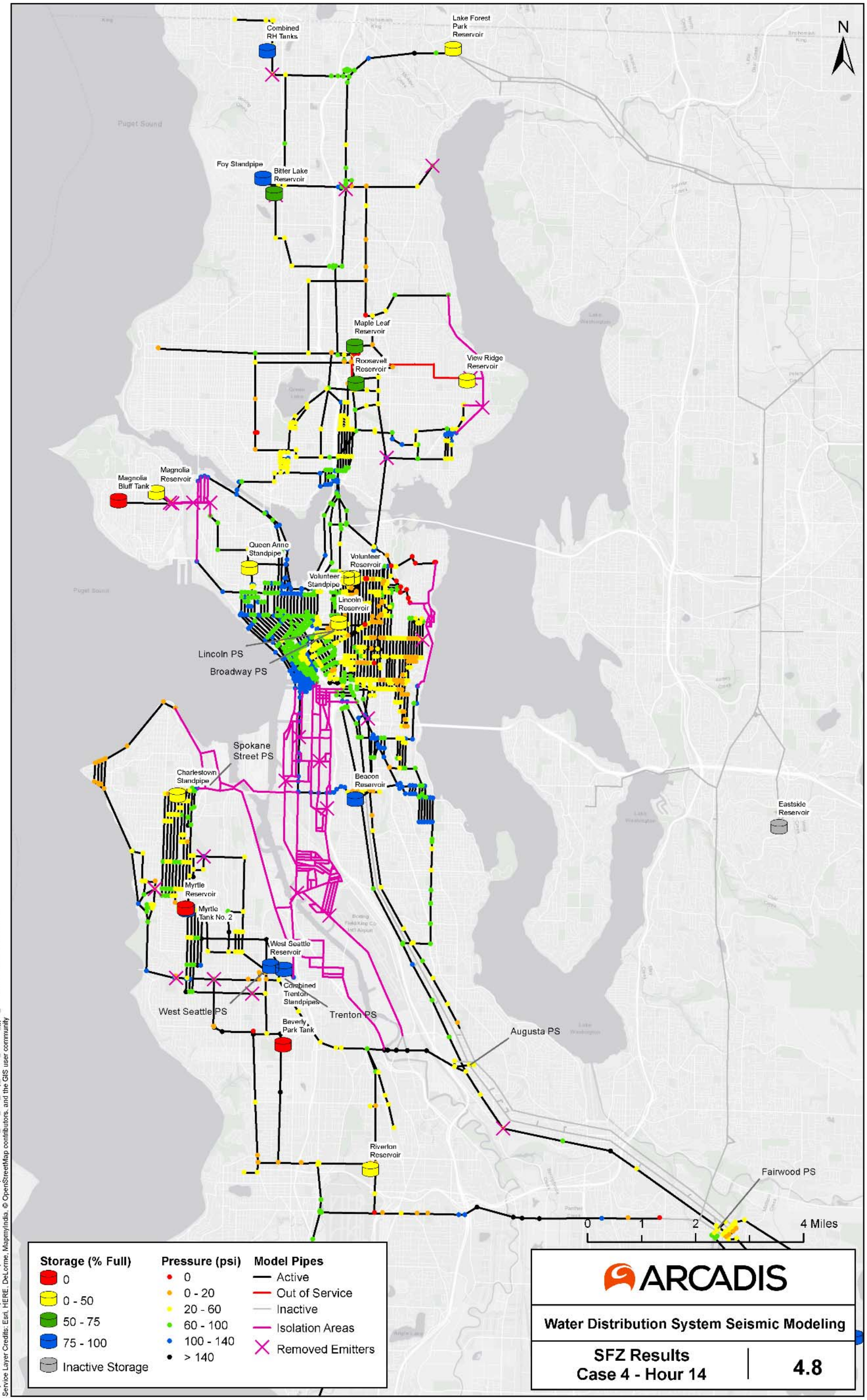

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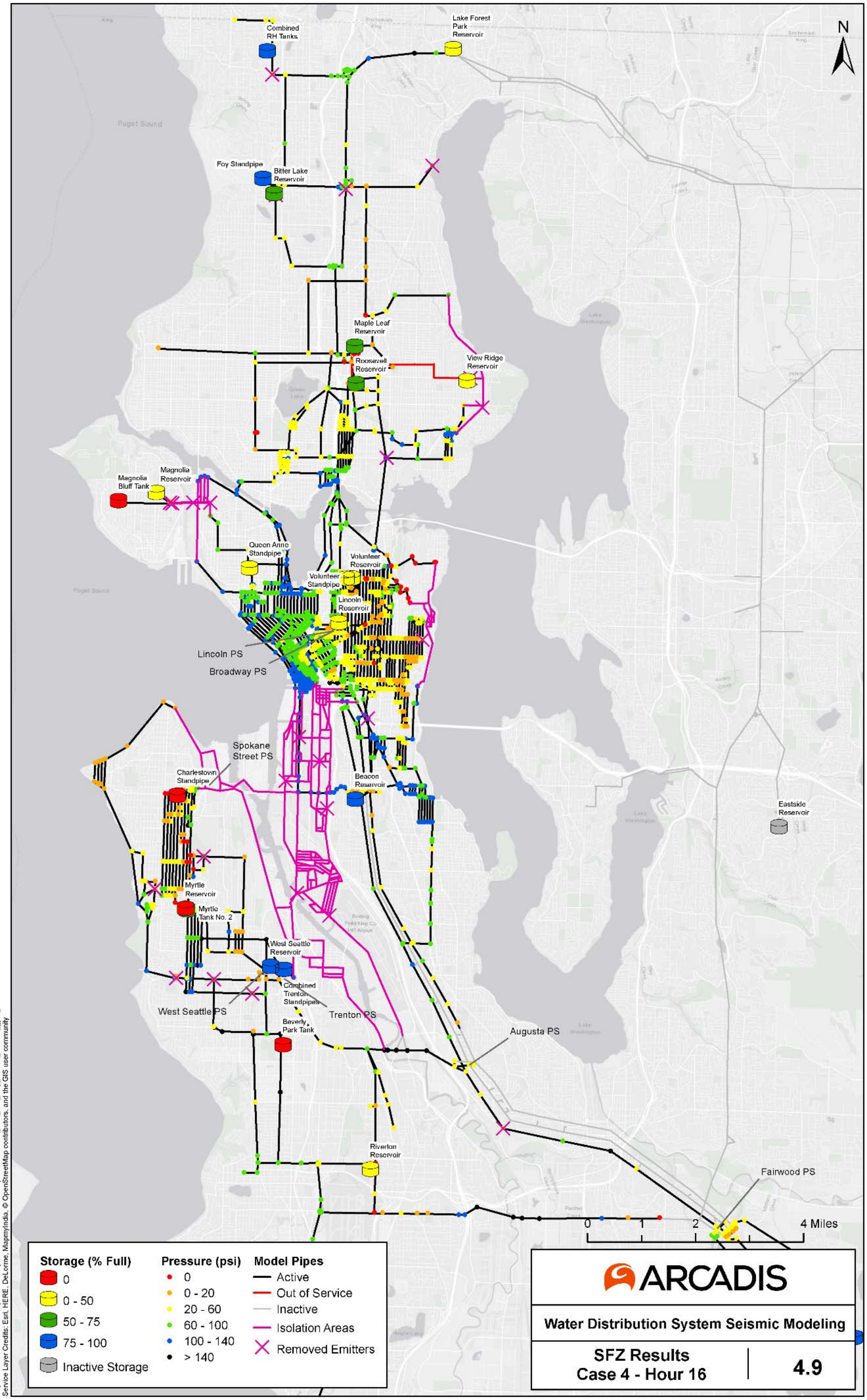

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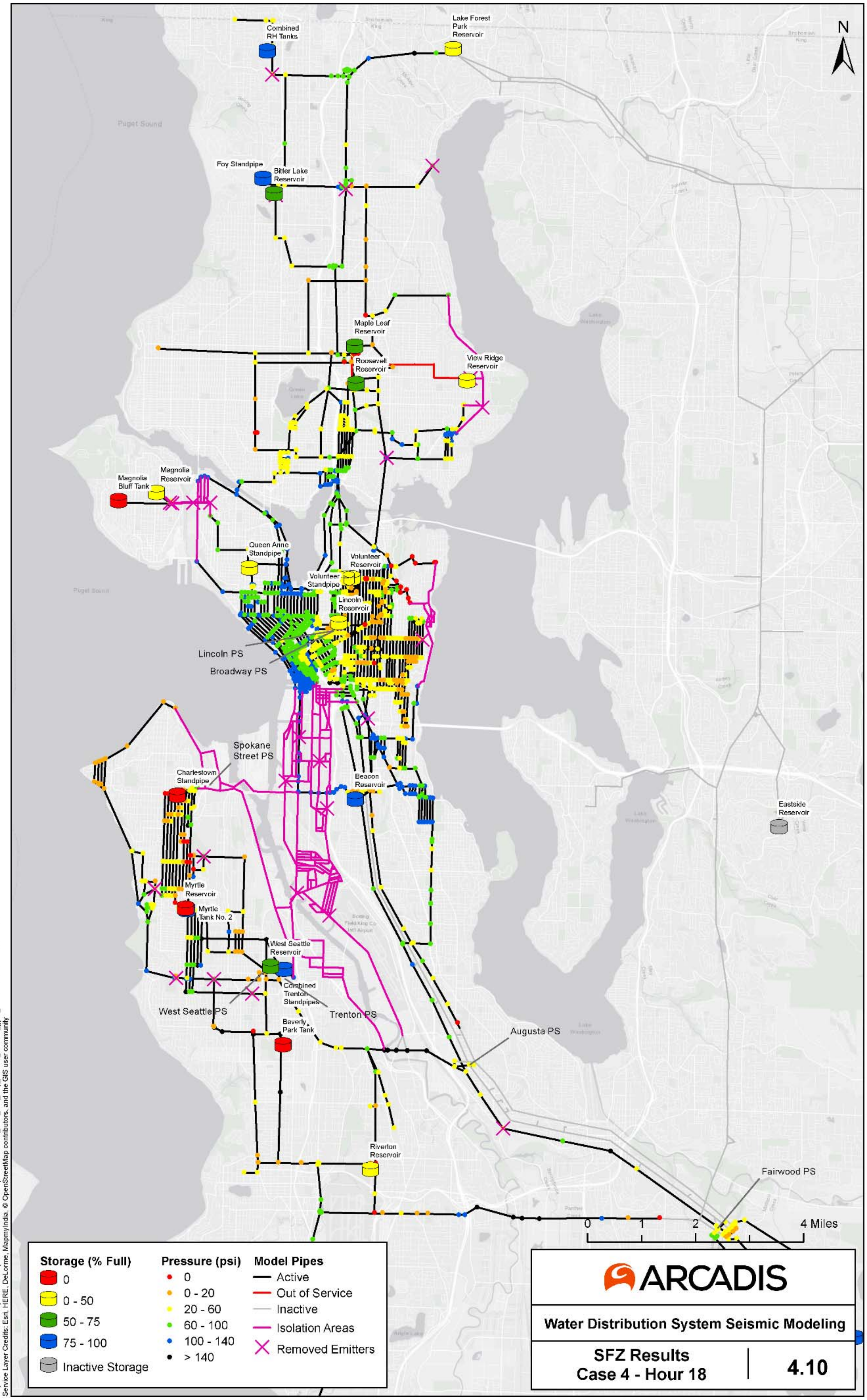

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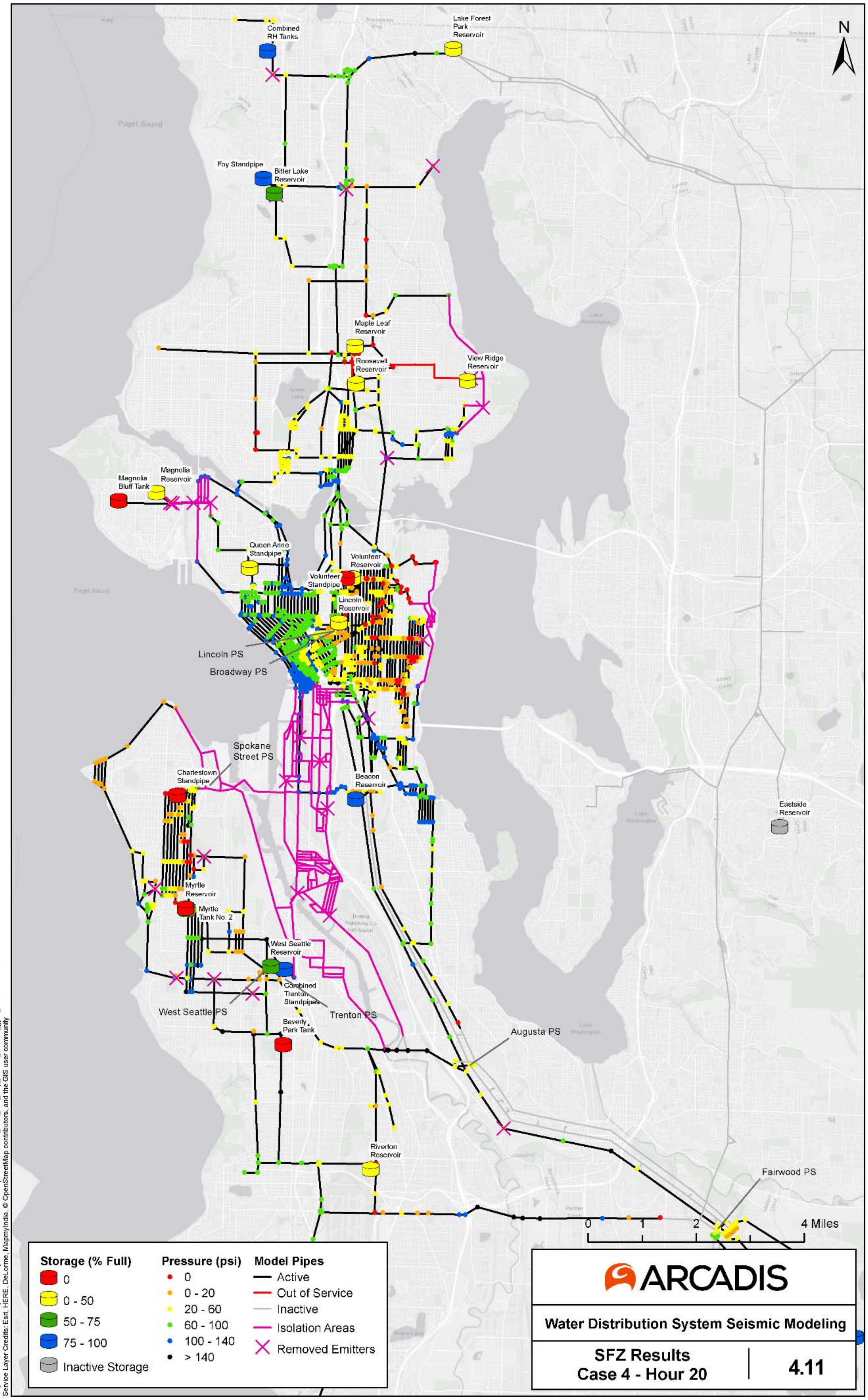

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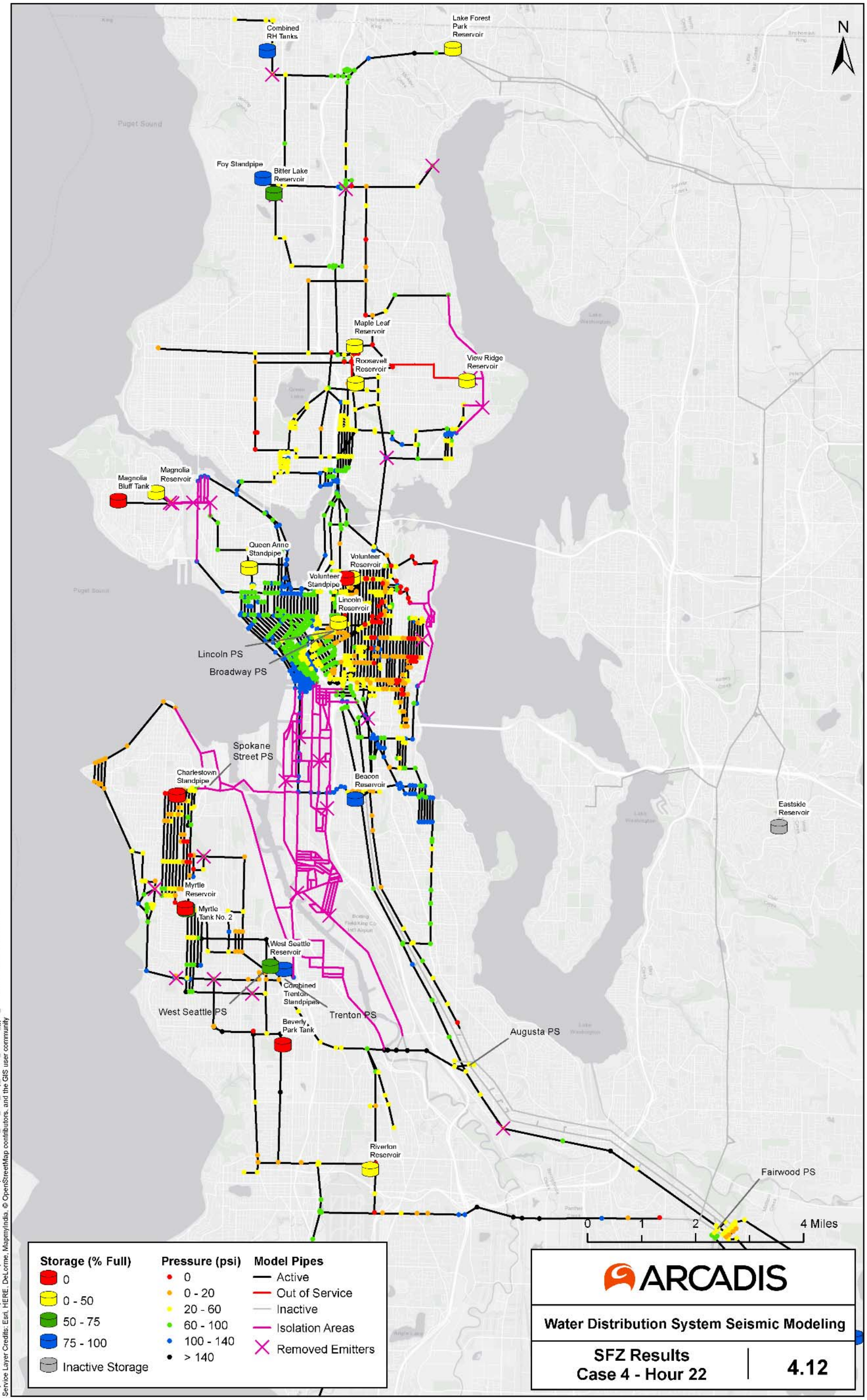
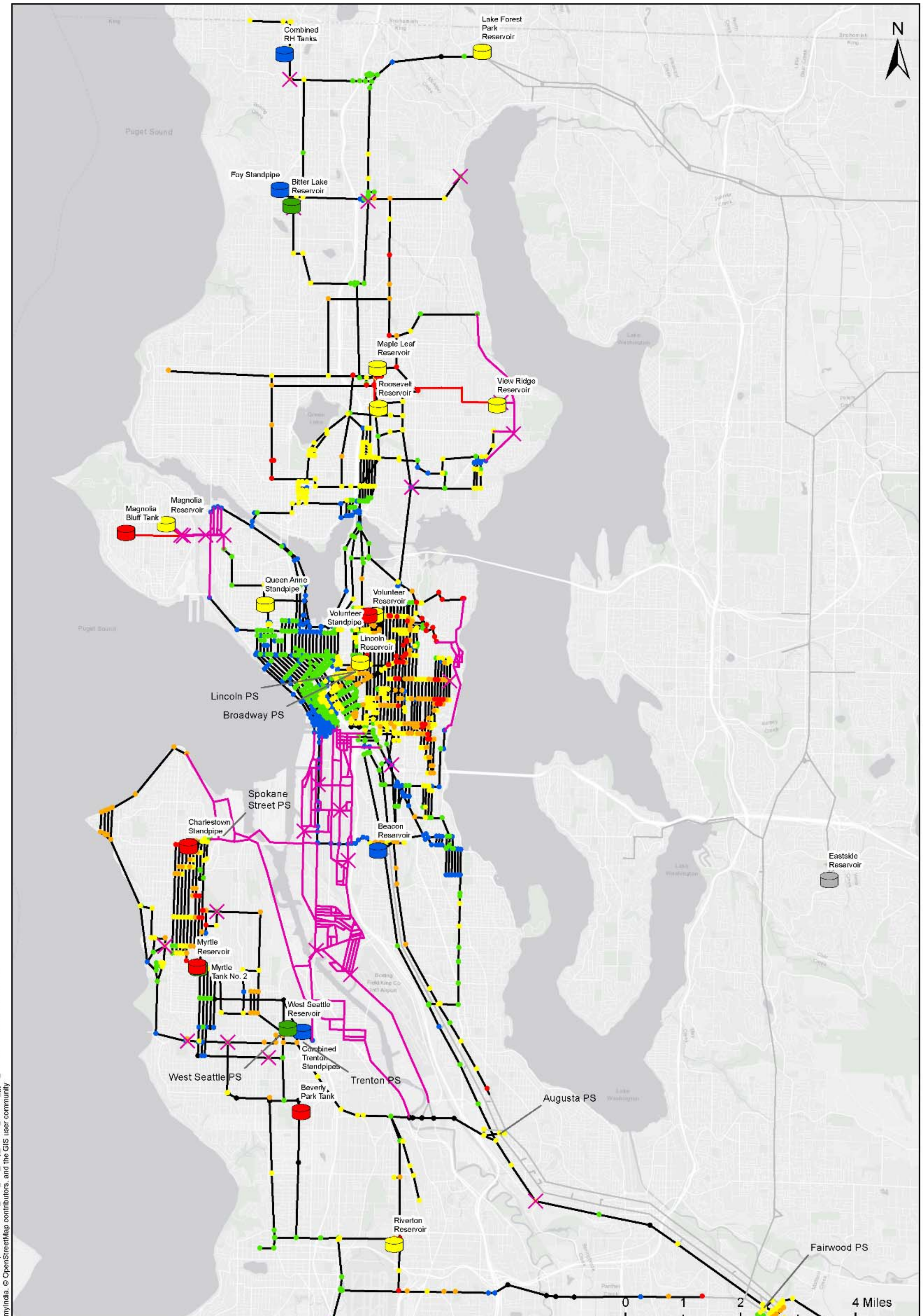


N
Puget Sound
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Lincoln PS
Broadway PS
Spokane Street PS
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
West Seattle PS
Trenton PS
Beverly Park Tank
Augusta PS
Riverton Reservoir
Fairwood PS
0
1
2
4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
Removed Emitters
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 4 - Hour 22
4.12



Water Distribution System Seismic Modeling

SFZ Results Case 4 - Hour 24 **4.13**

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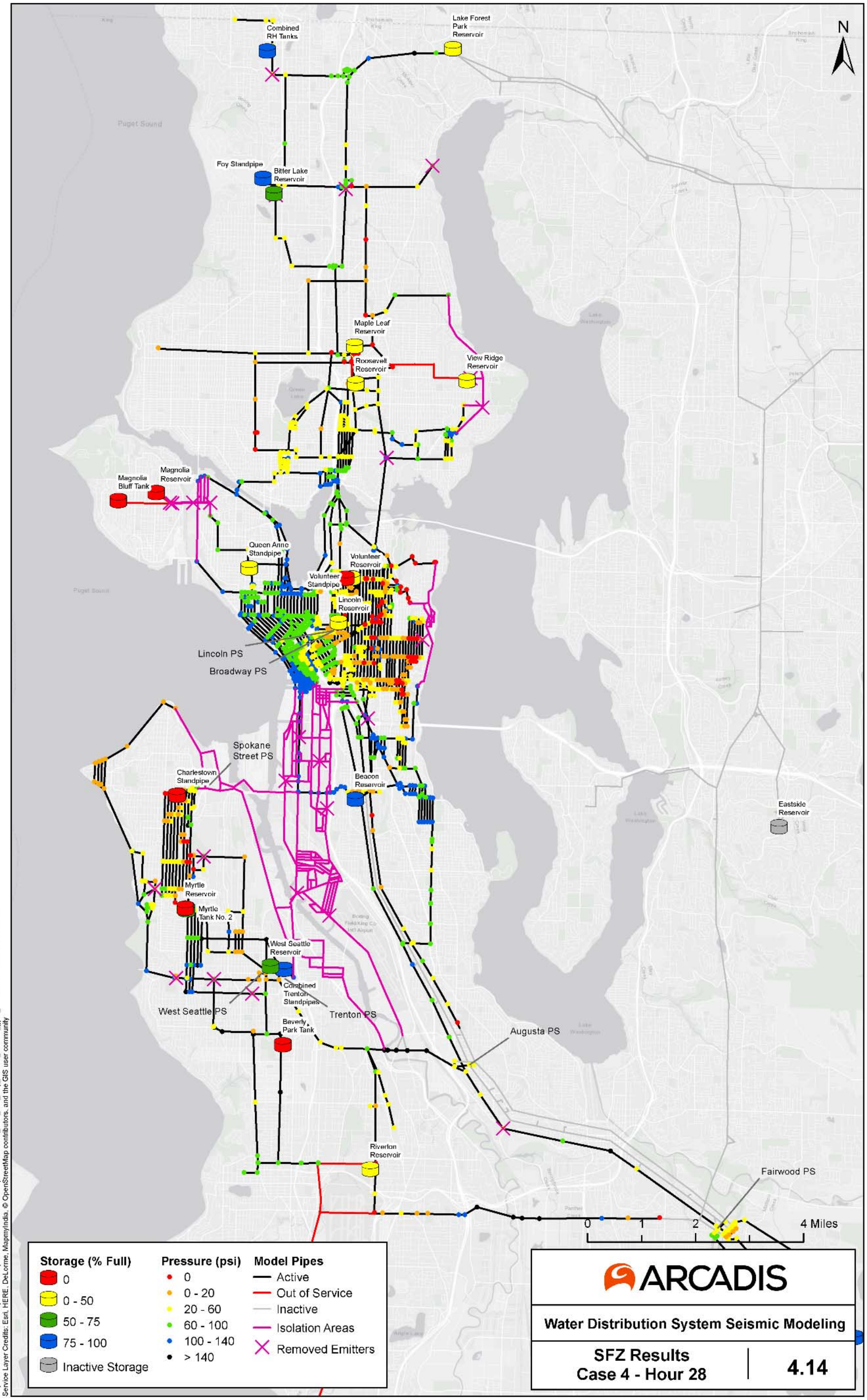

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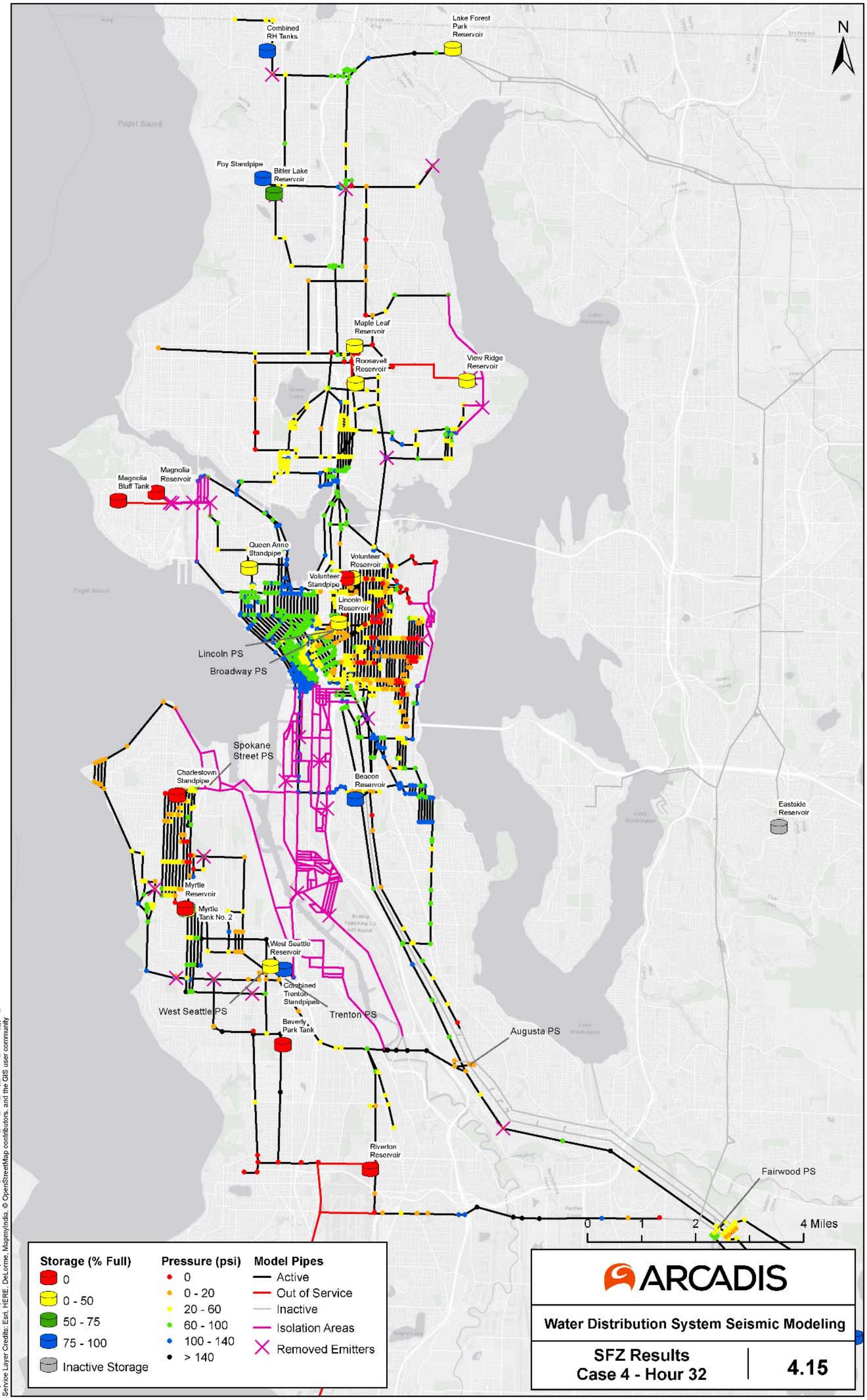

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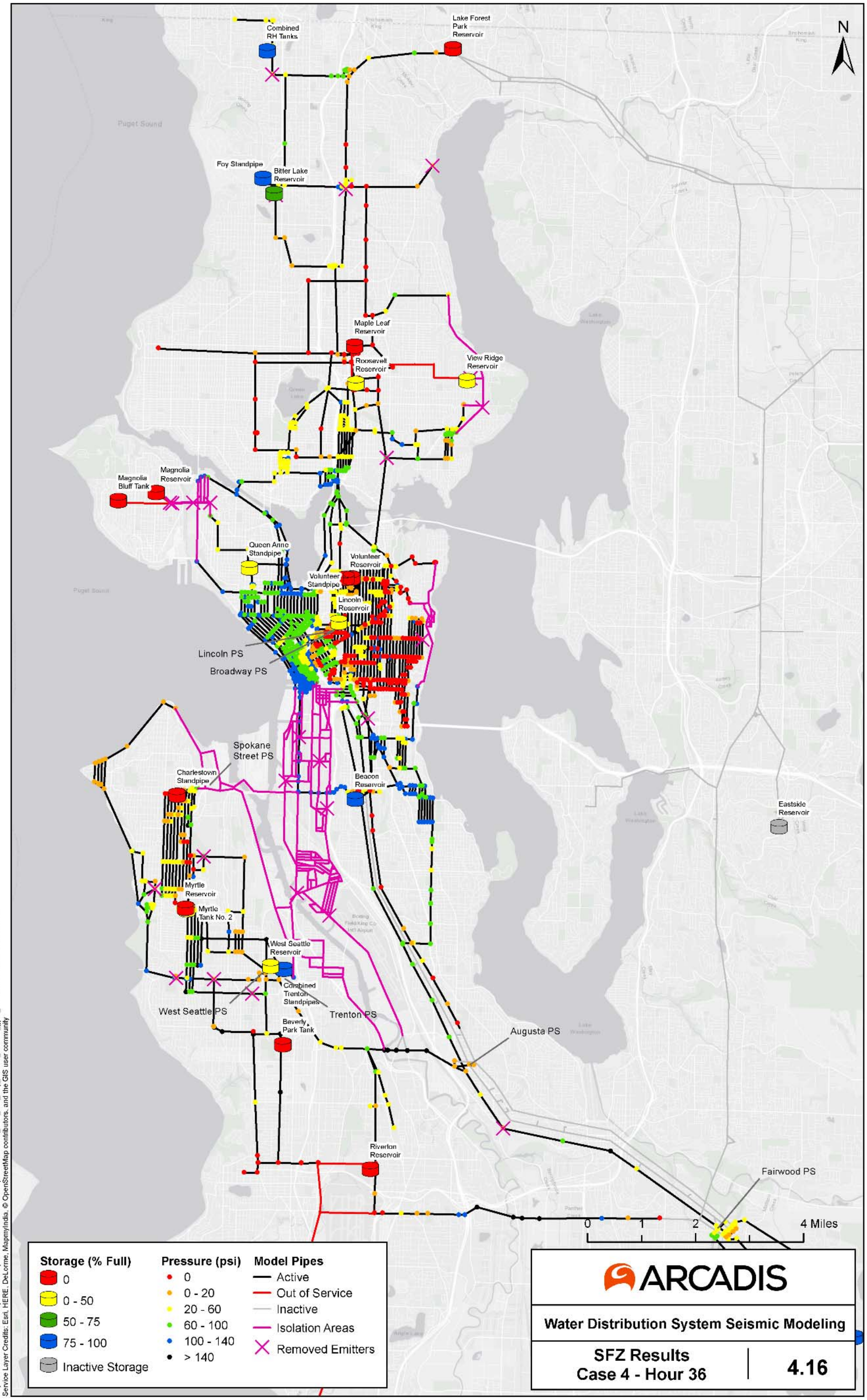

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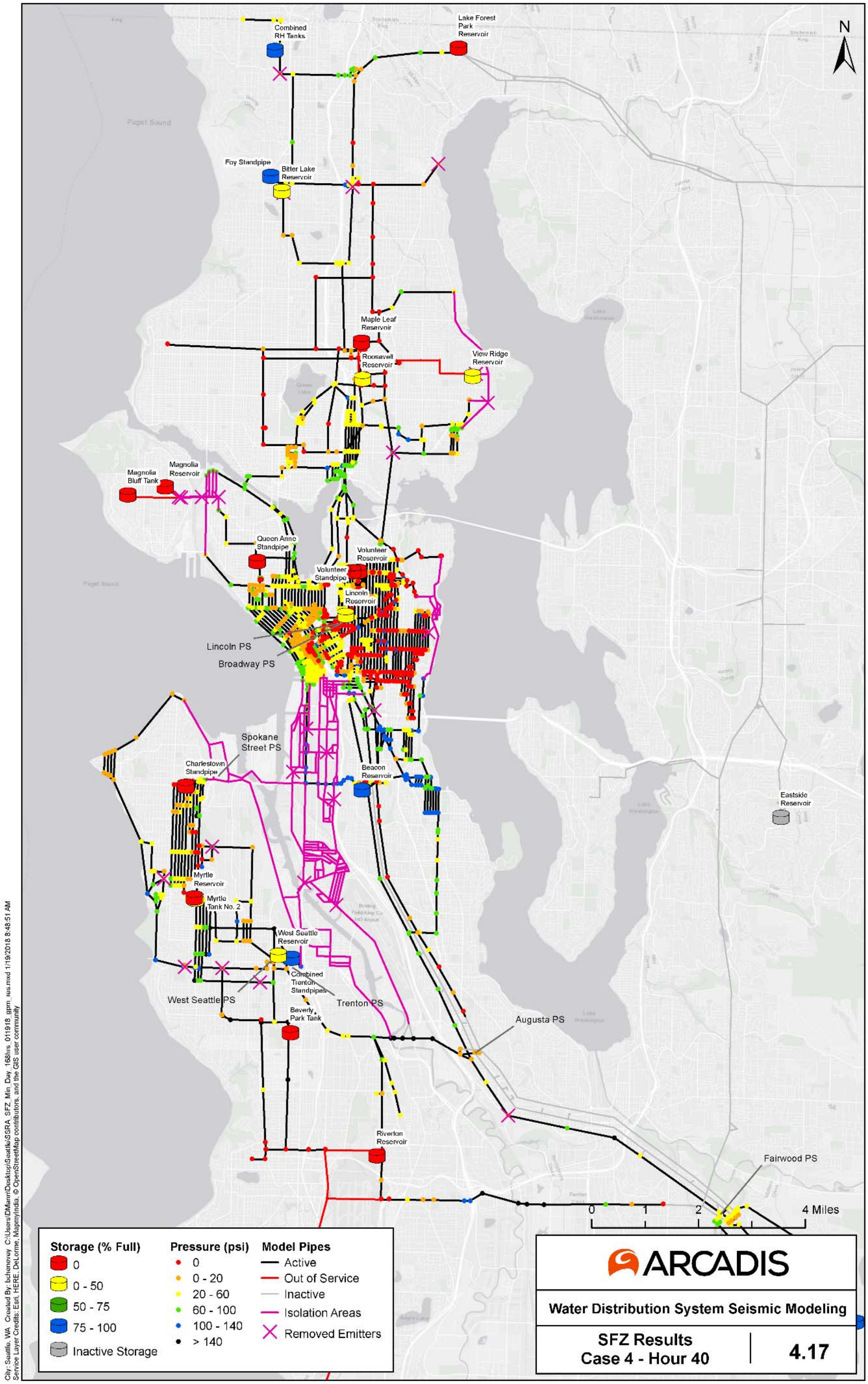
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0 1 2 4 Miles
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100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
Removed Emitters
ARCADIS
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4.17
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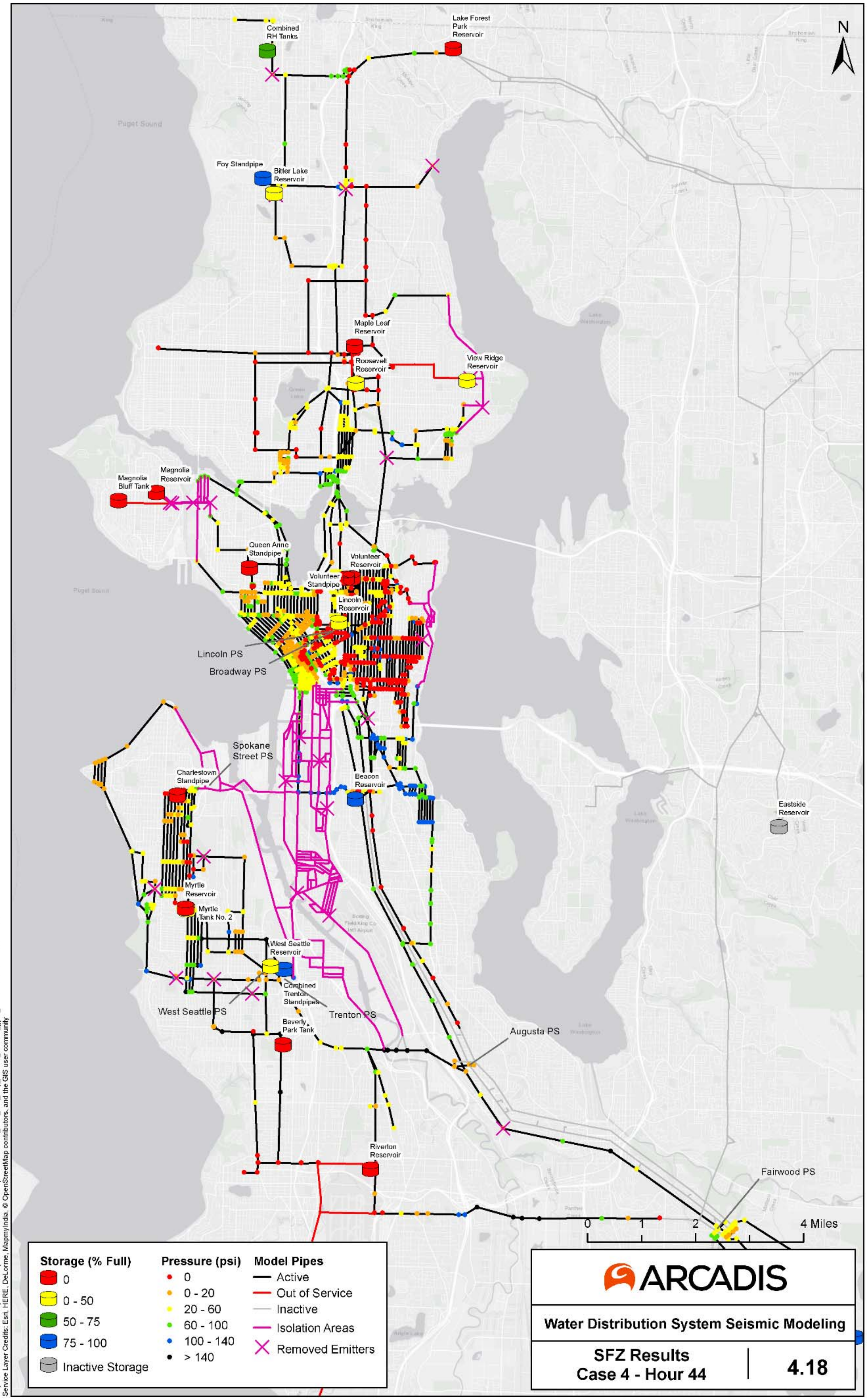

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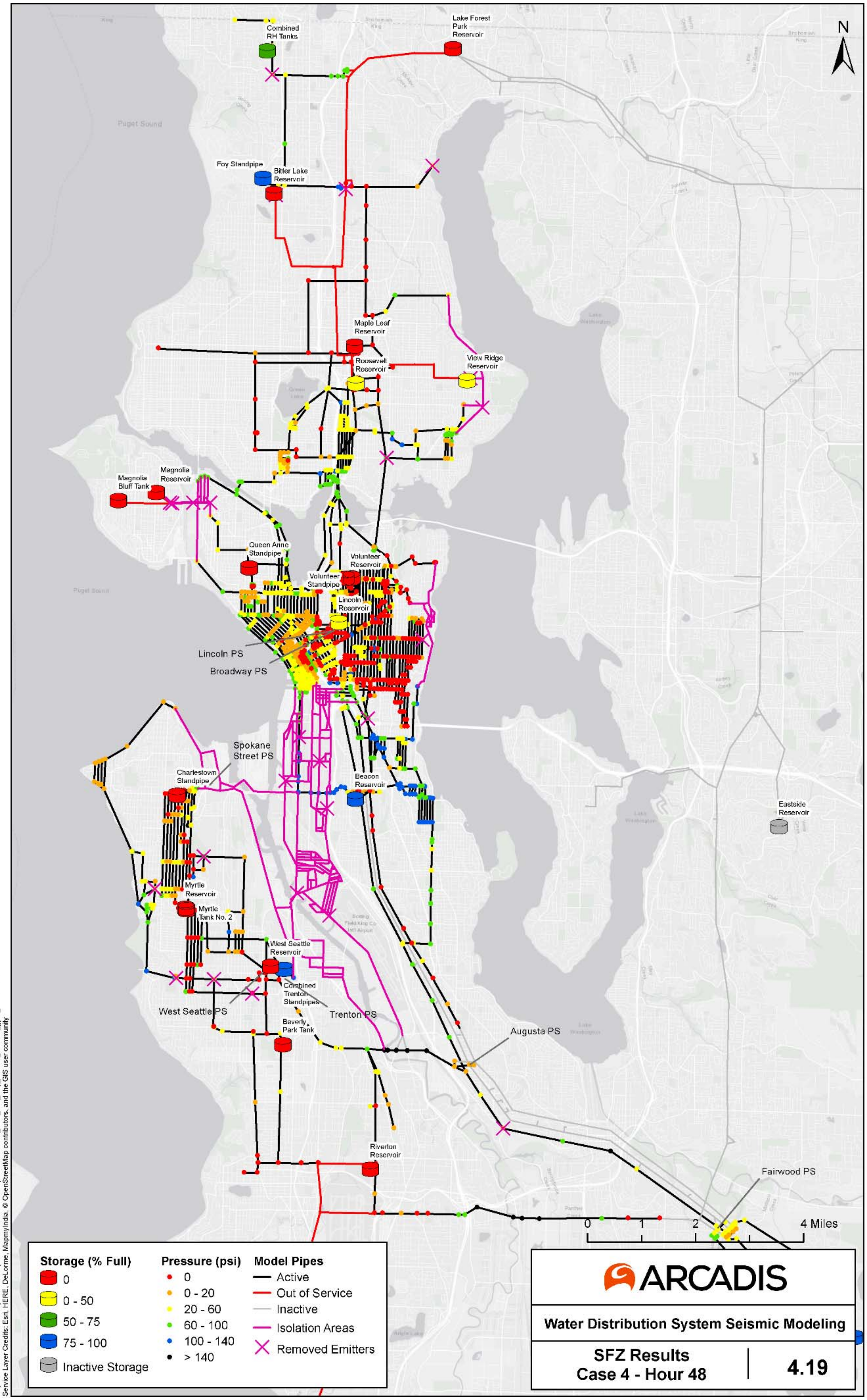

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M7.0 Seattle Fault Zone Case 5 (No Improvements Except Cedar Transmission System is Assumed to be Functional) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/2/2018

Seattle Fault Seismic Event

Case 5 Same as "Base" case
CRPL #1, #2, #3 are Functional

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	329,851	303,593	26,259	92%	251.1
3	326,218	289,682	36,535	82%	210.5
12	261,364	240,666	20,698	69%	123.9
22	218,461	200,709	17,752	66%	56.9
32	214,803	197,800	17,003	64%	26.1
48	180,543	164,584	15,958	60%	16.5

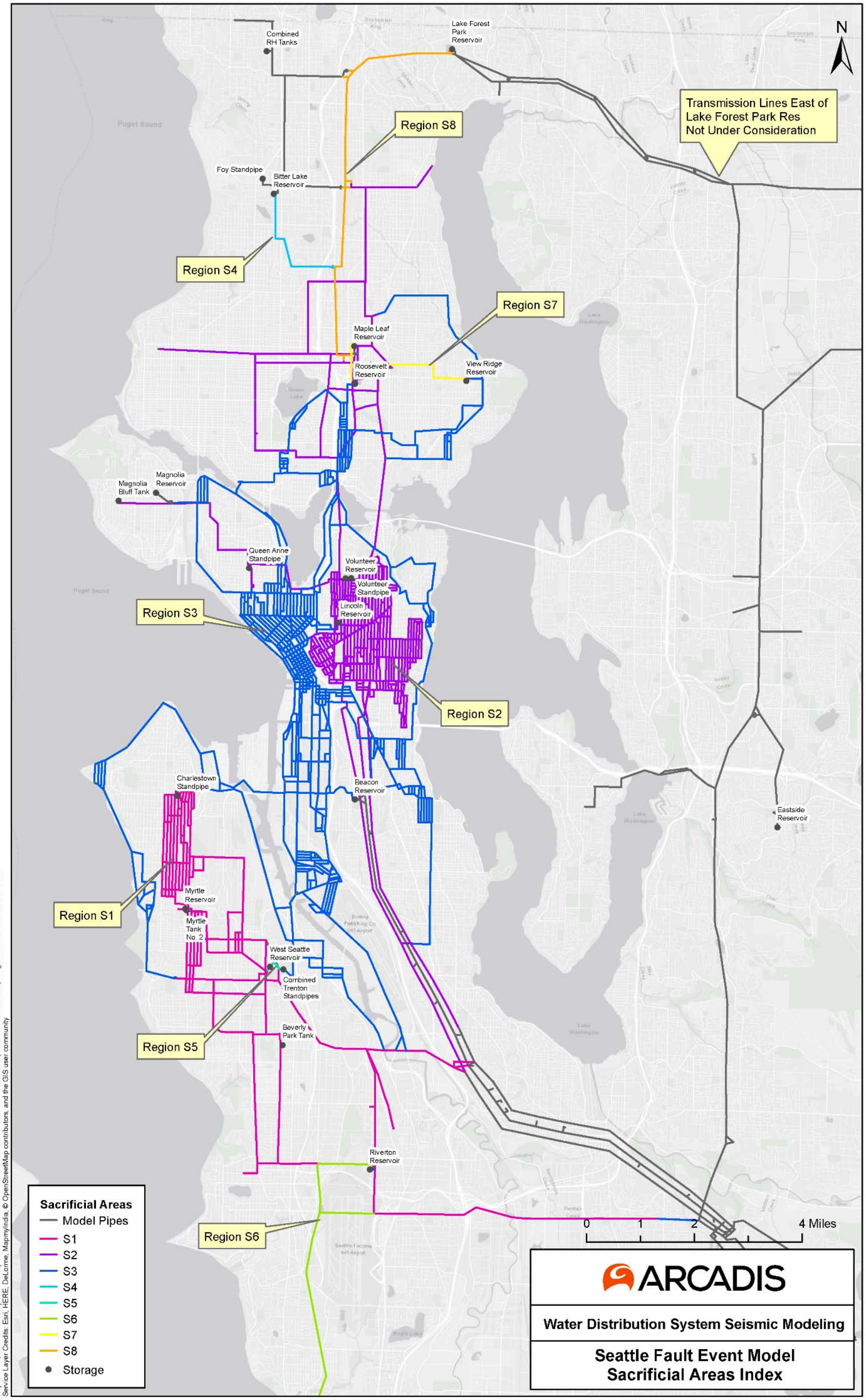
Model Regions Forced Out of Service During Simulation

Time	Region
3	S1
32	S4
35	S5

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index



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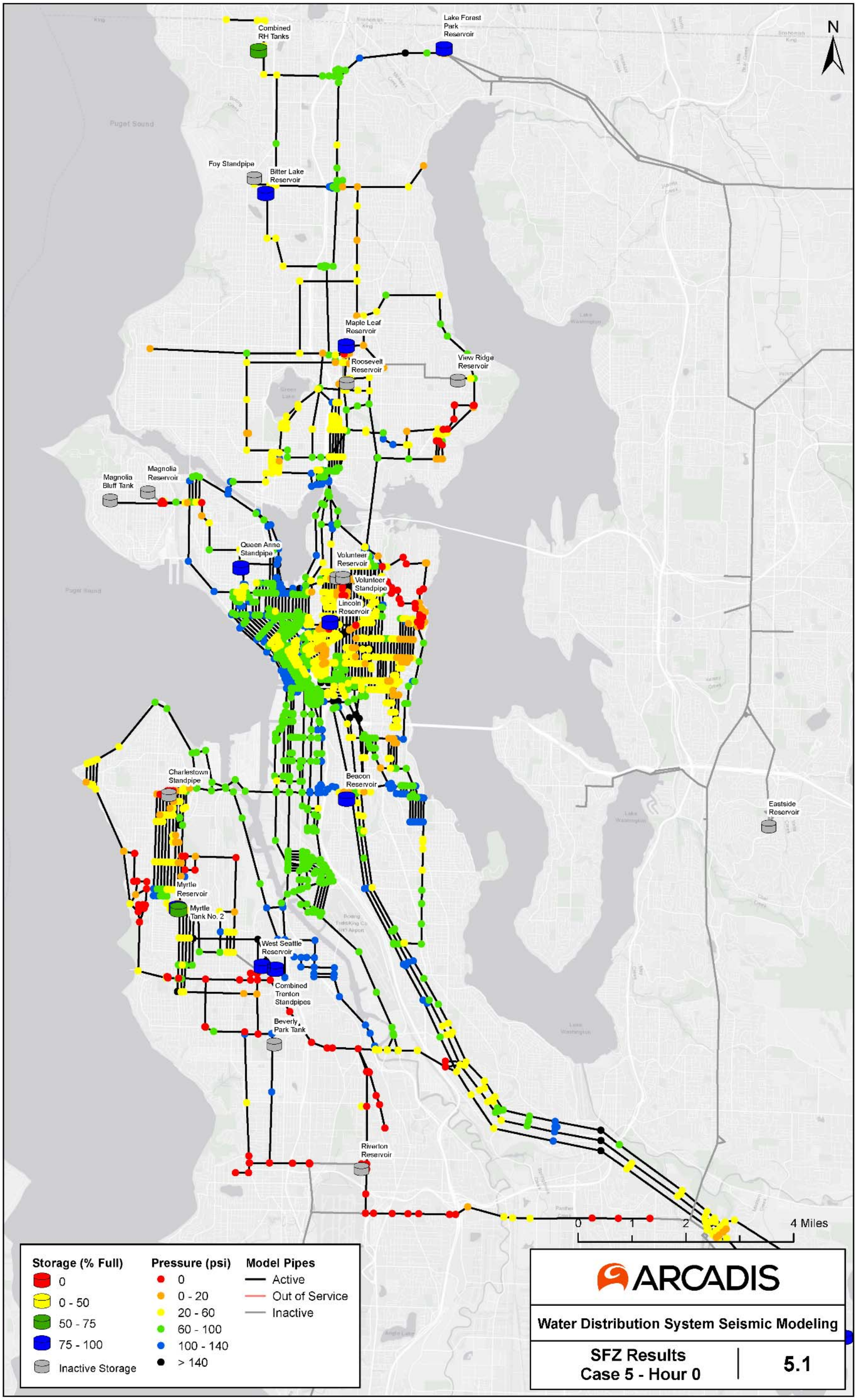
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Combined RH Tanks
Lake Forest Park Reservoir
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Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Lake Washington
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0 1 2 4 Miles
Storage (% Full)
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75 - 100
Inactive Storage
Pressure (psi)
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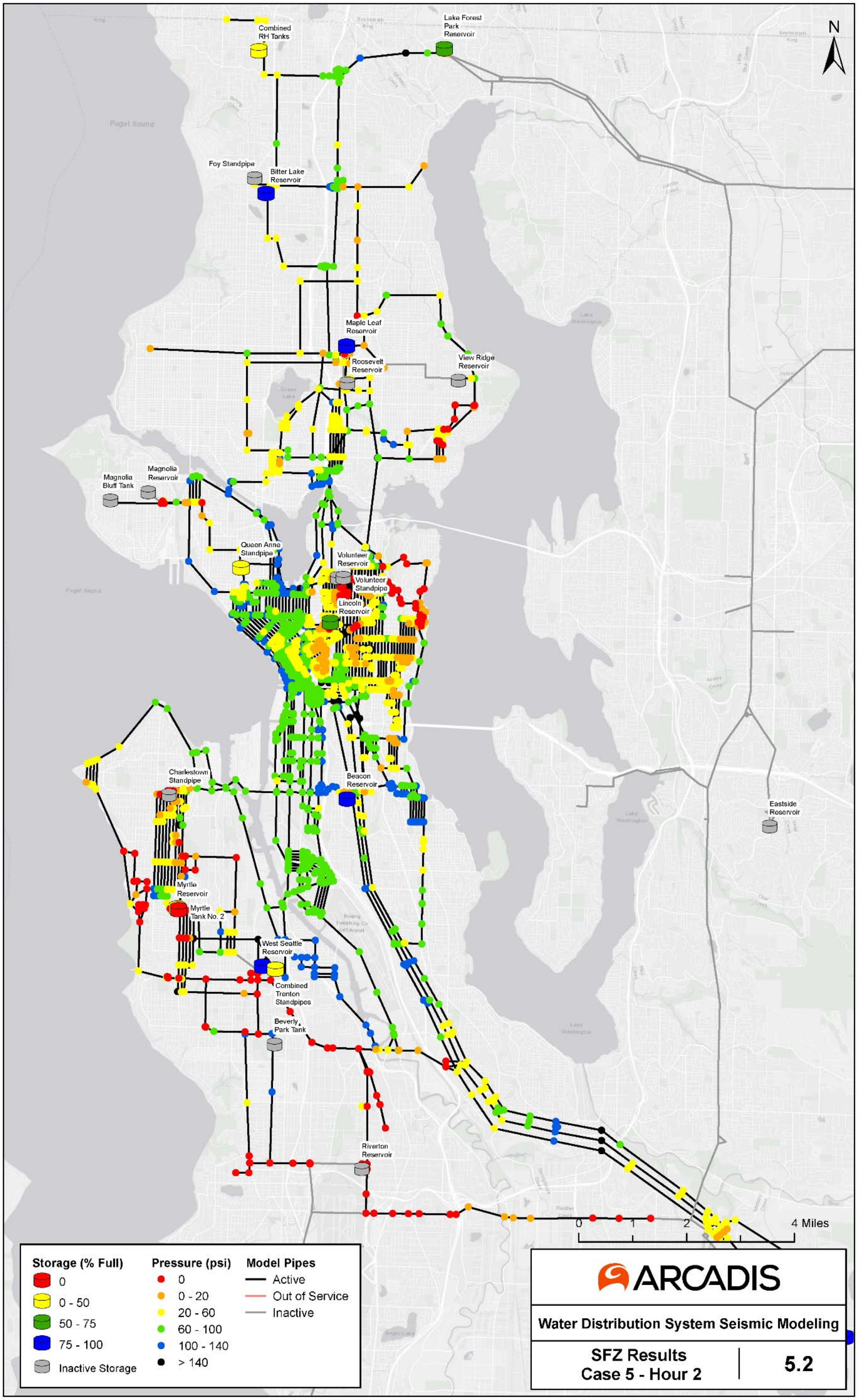
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 5 - Hour 0
5.1



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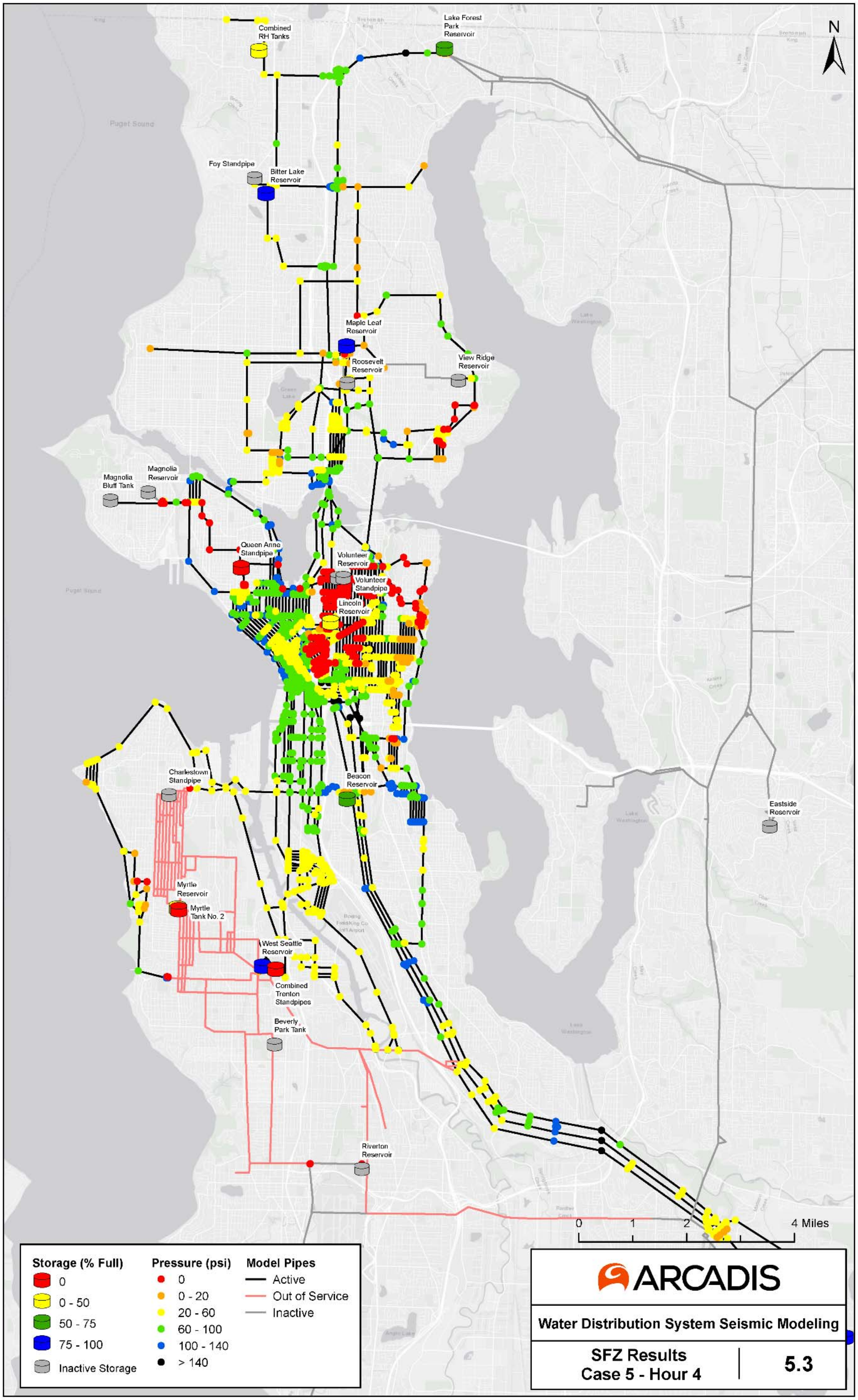

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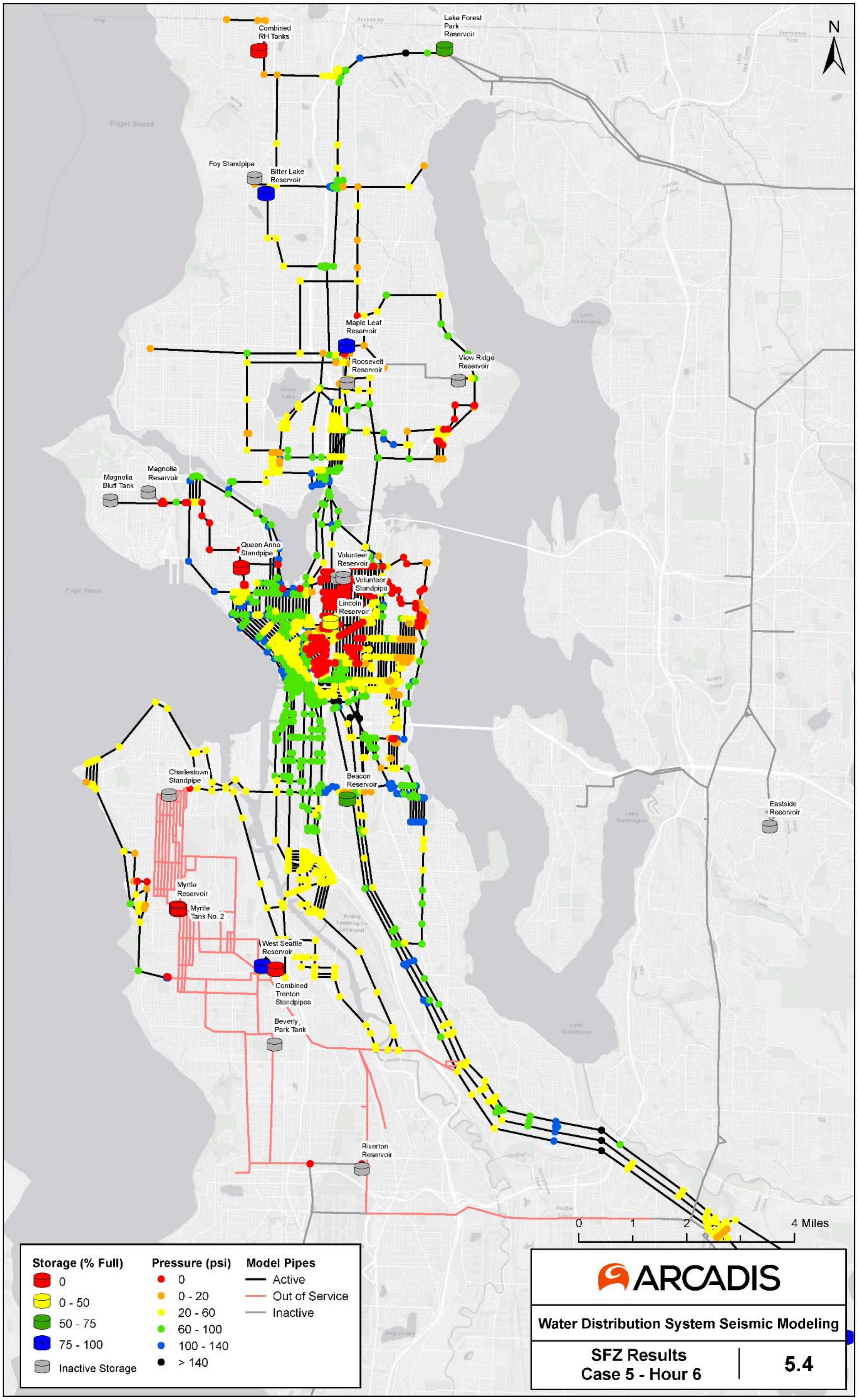
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ARCADIS
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Case 5 - Hour 6
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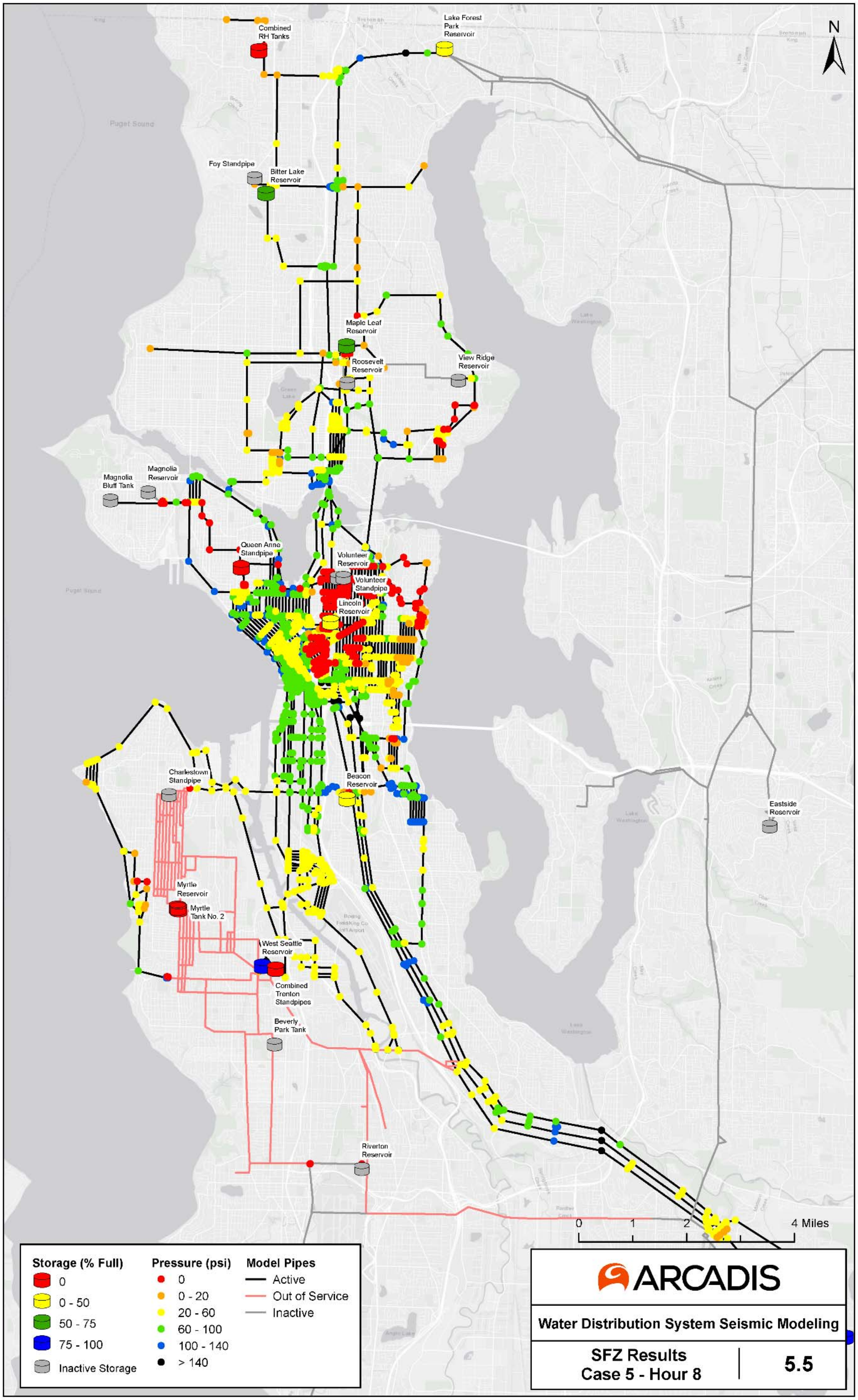

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Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 8

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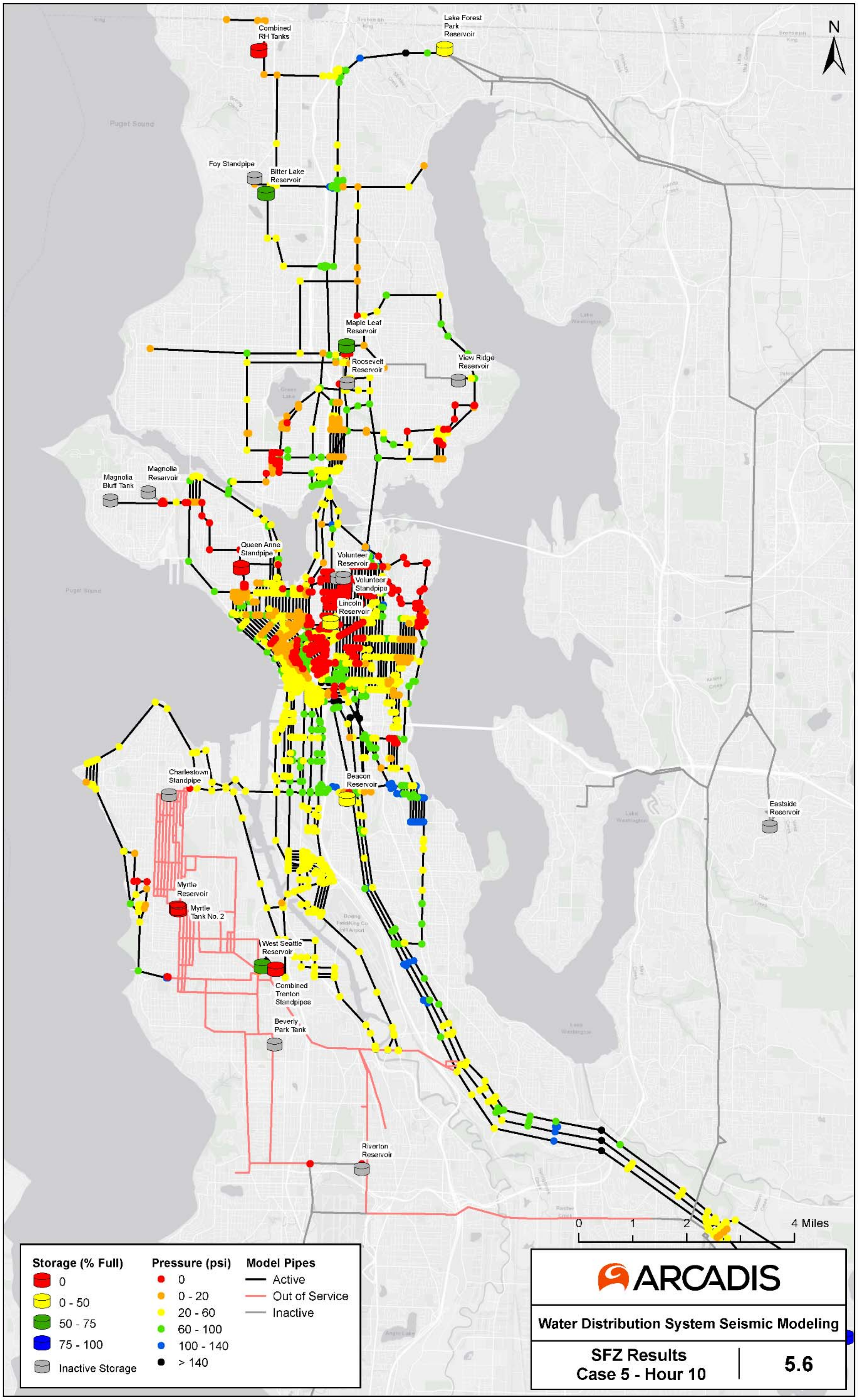
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SFZ Results
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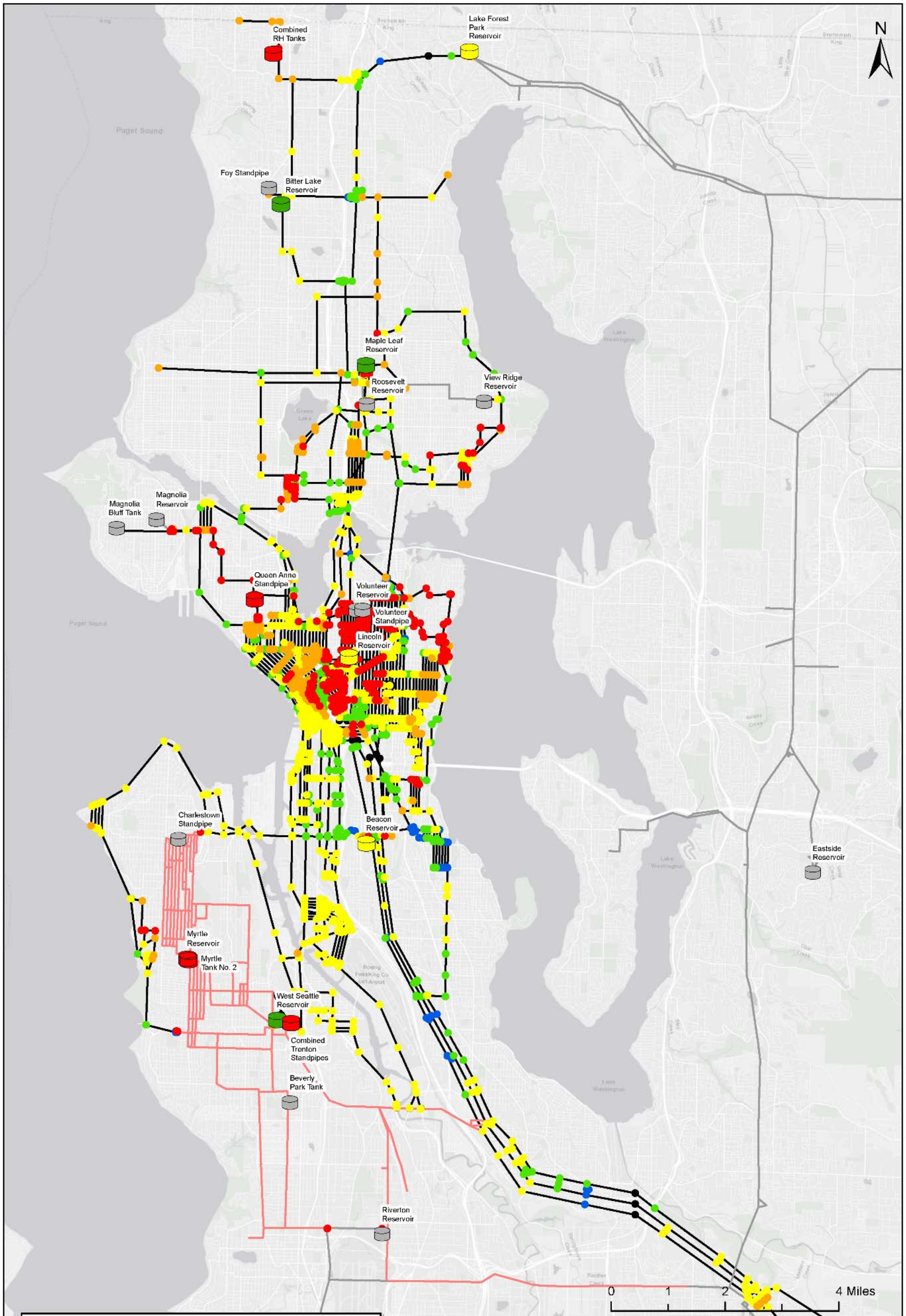

Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 12

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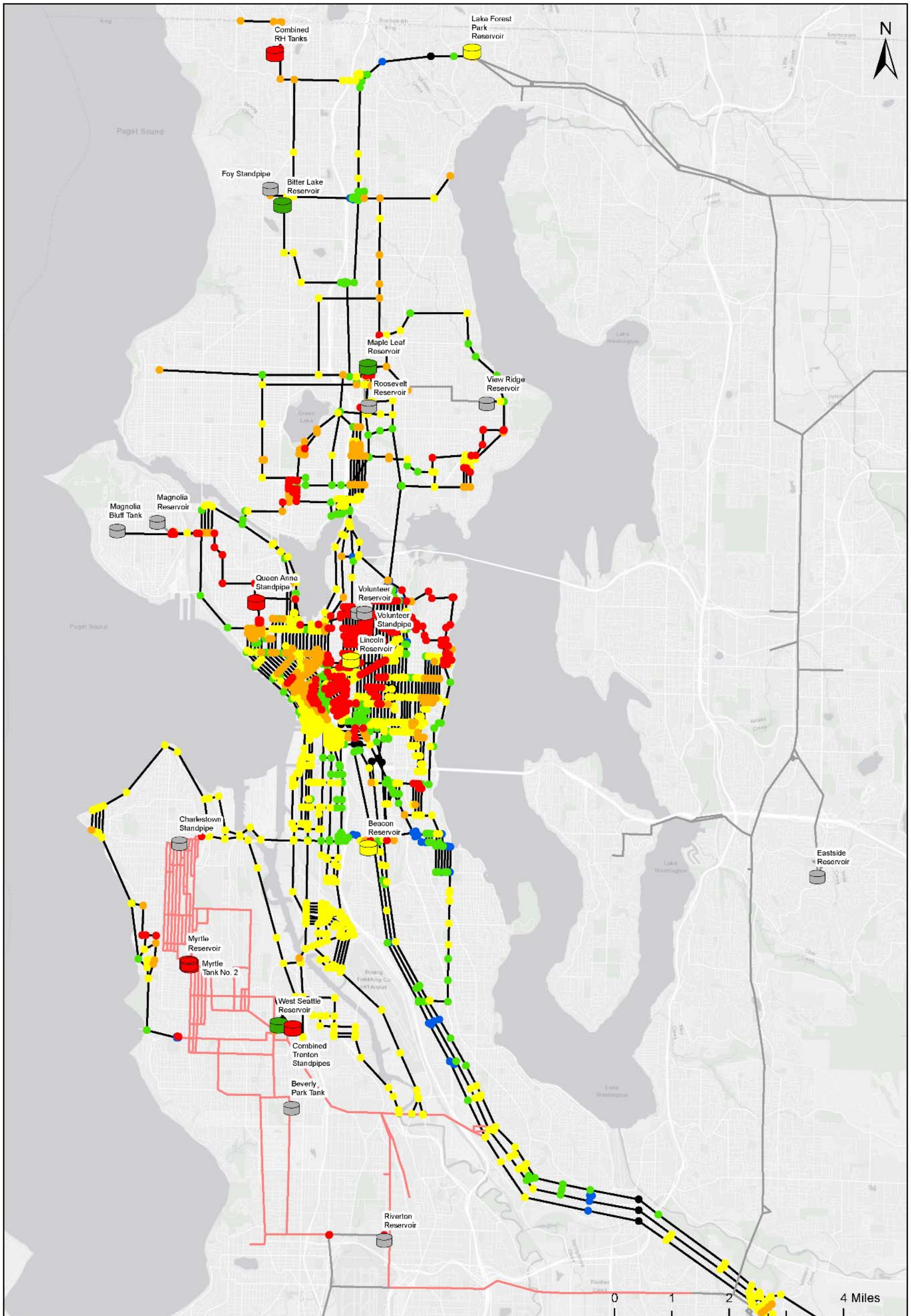

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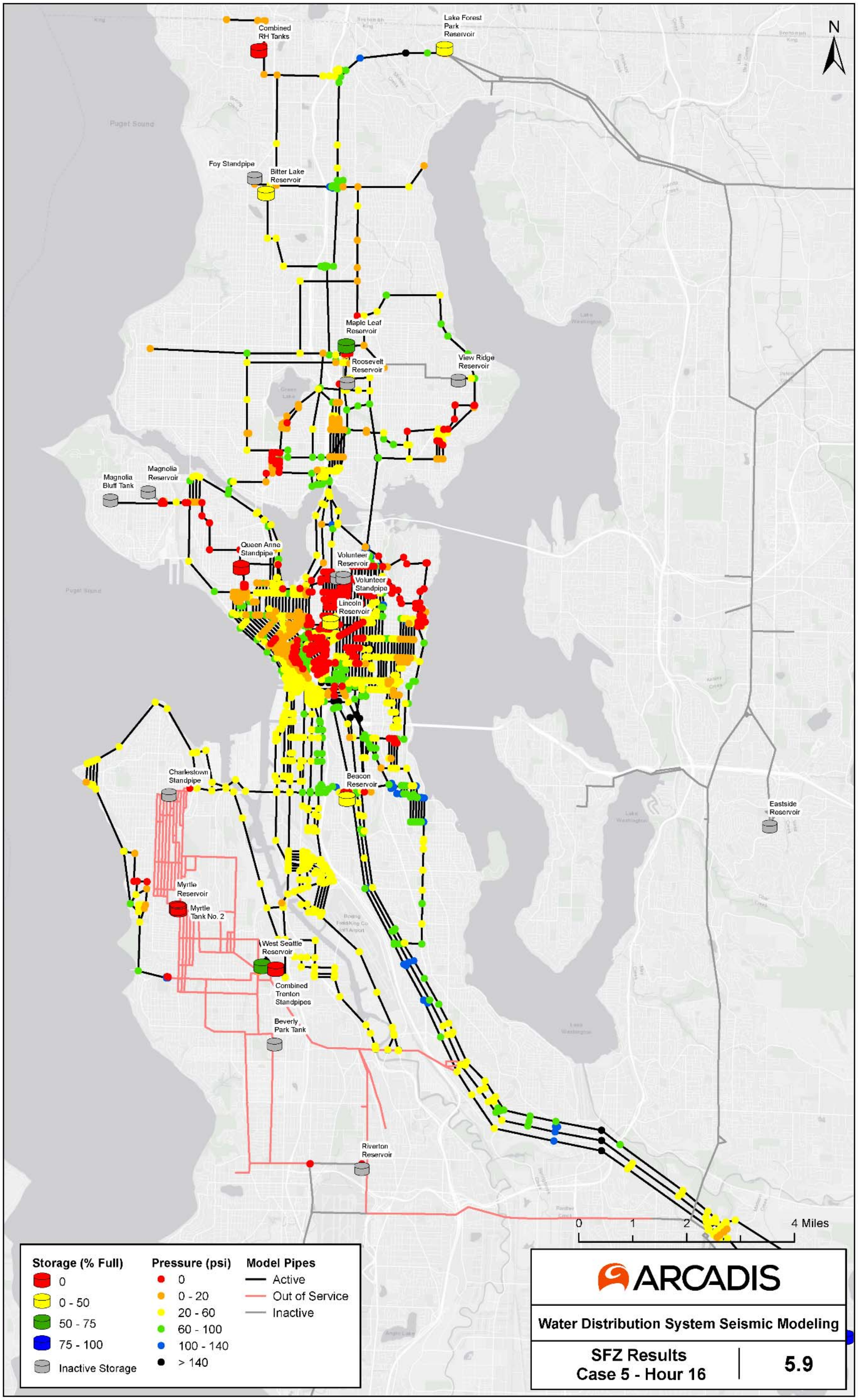
Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 14

5.8



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ARCADIS
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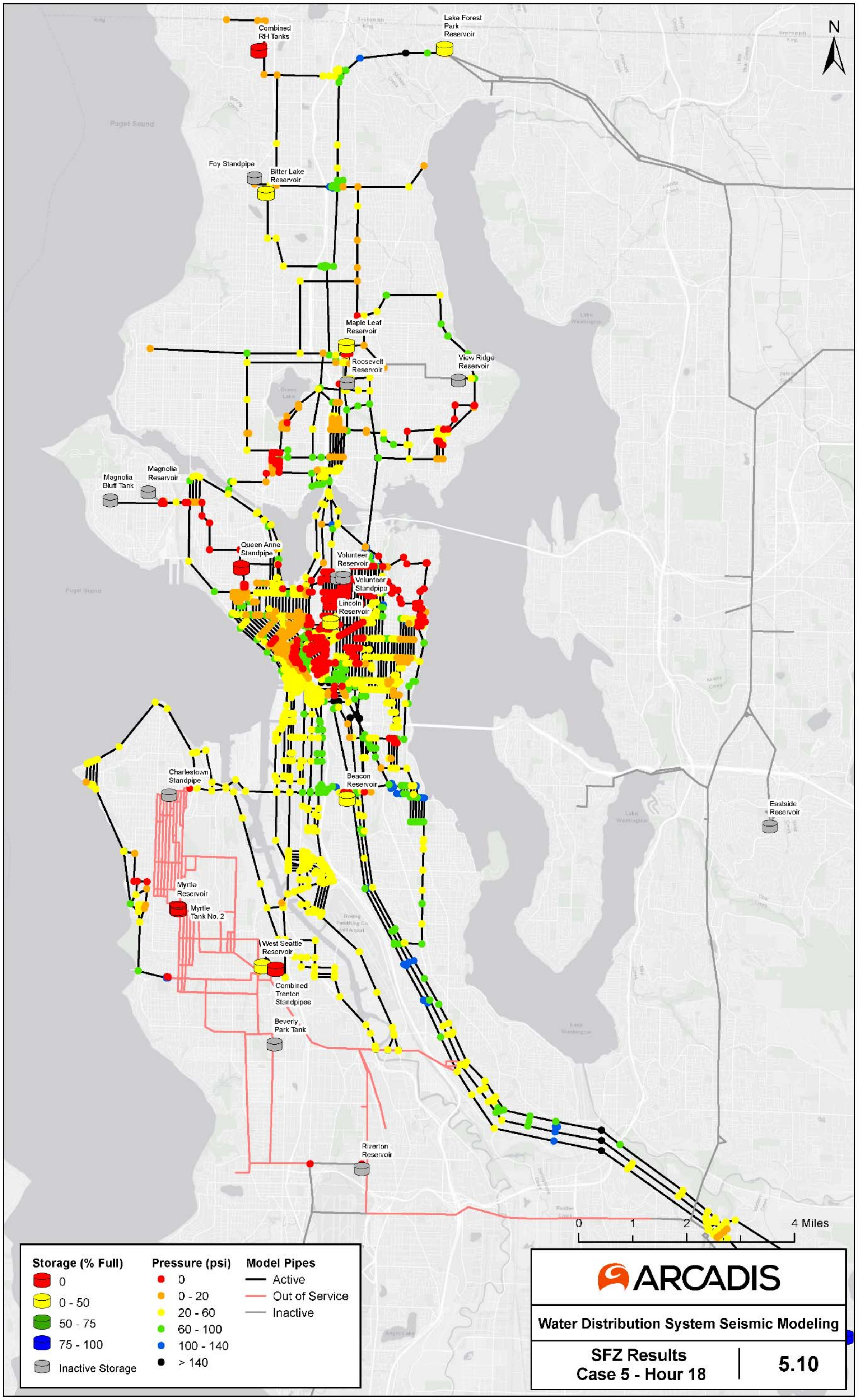
Case 5 - Hour 16
5.9



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Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 18

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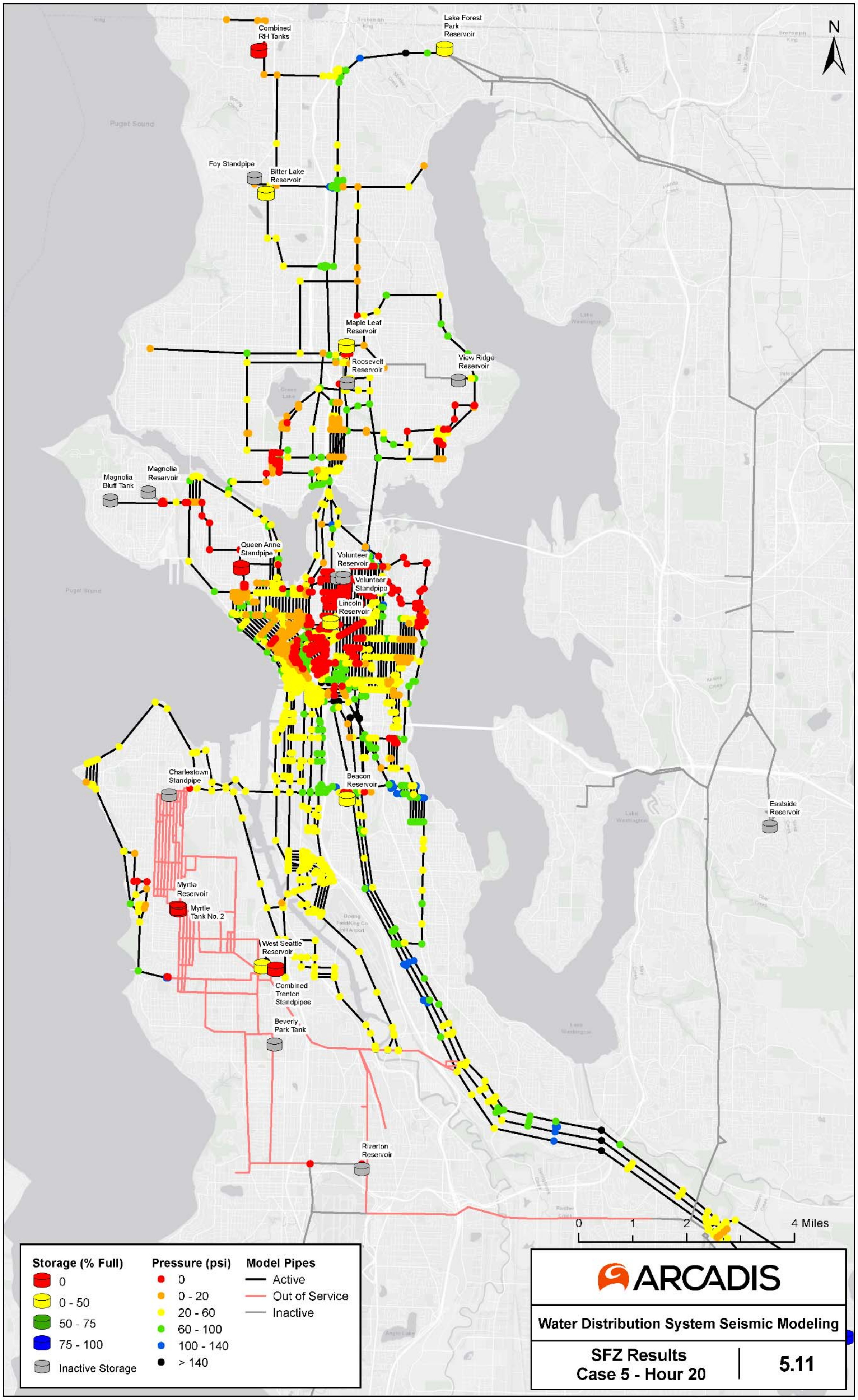

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ARCADIS
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SFZ Results
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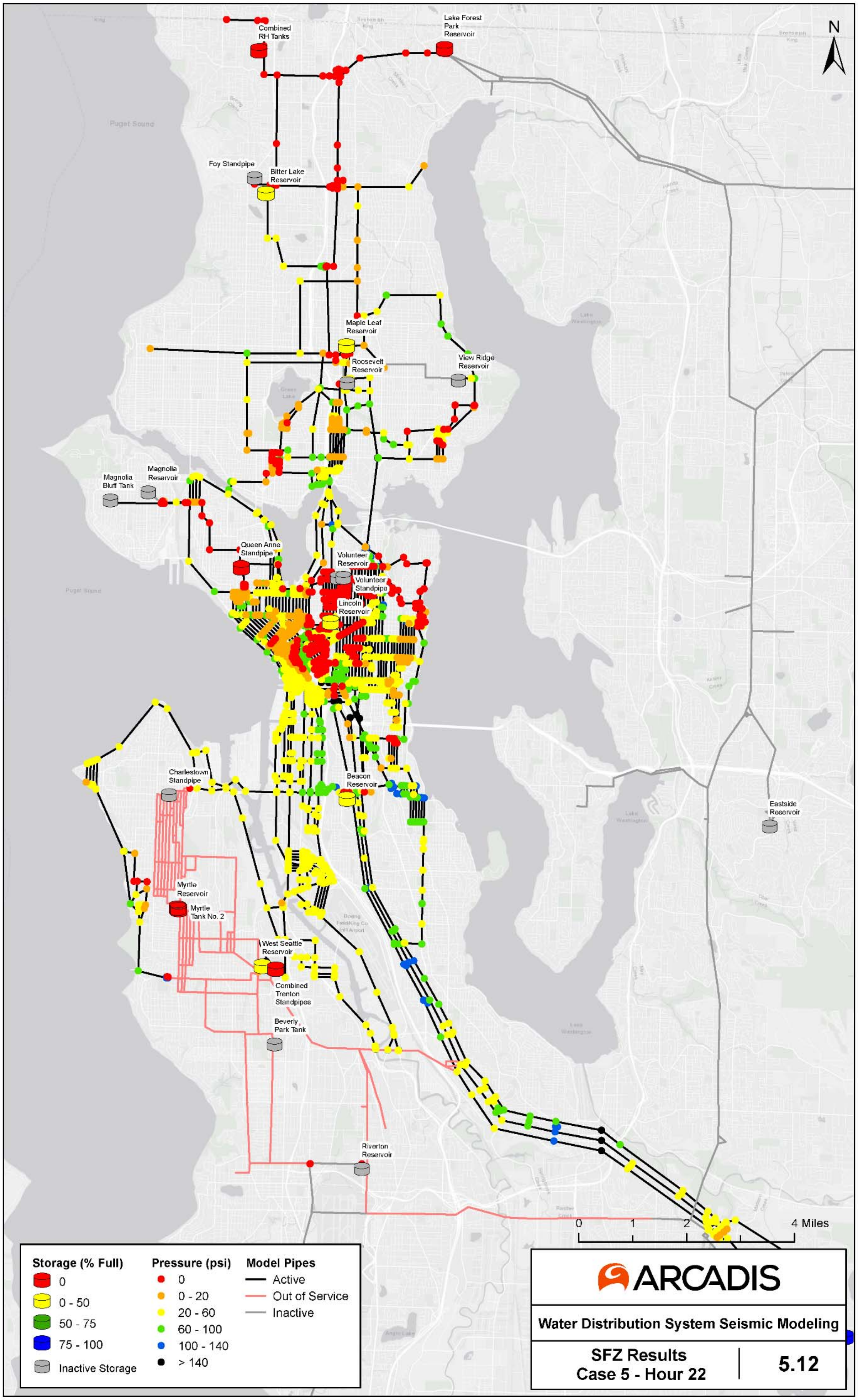

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SFZ Results
Case 5 - Hour 22
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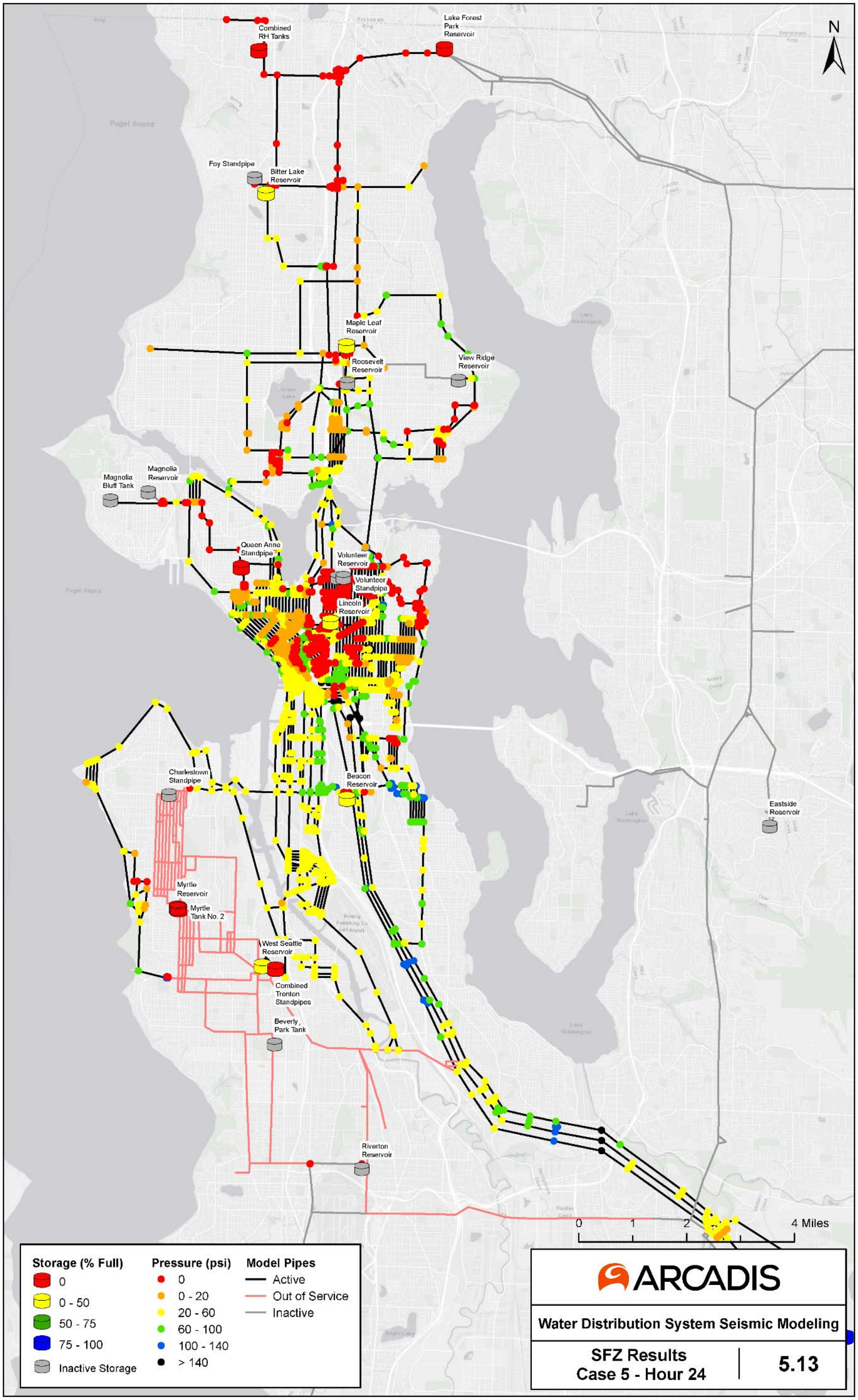

Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 24

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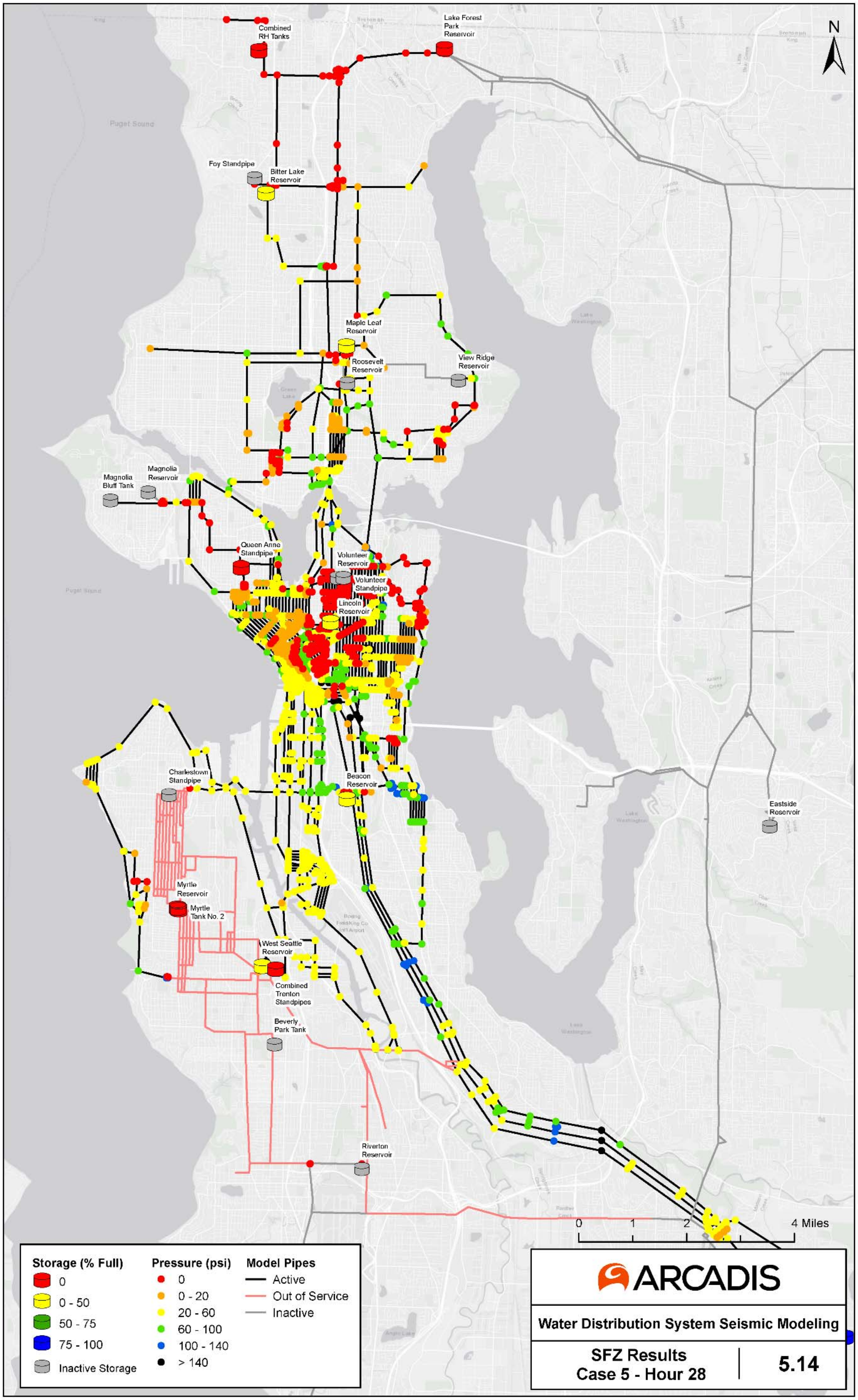

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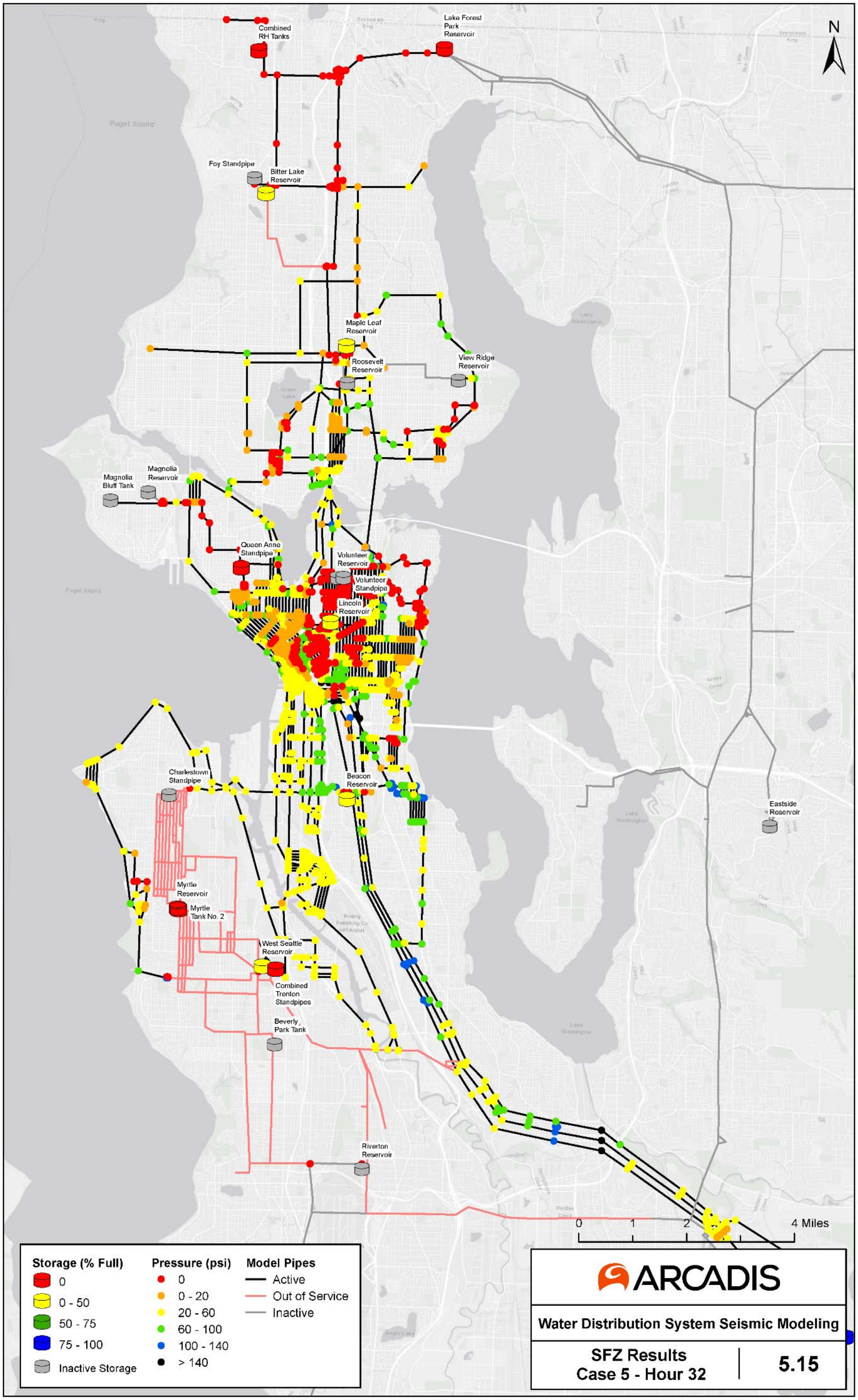
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ARCADIS
Water Distribution System Seismic Modeling
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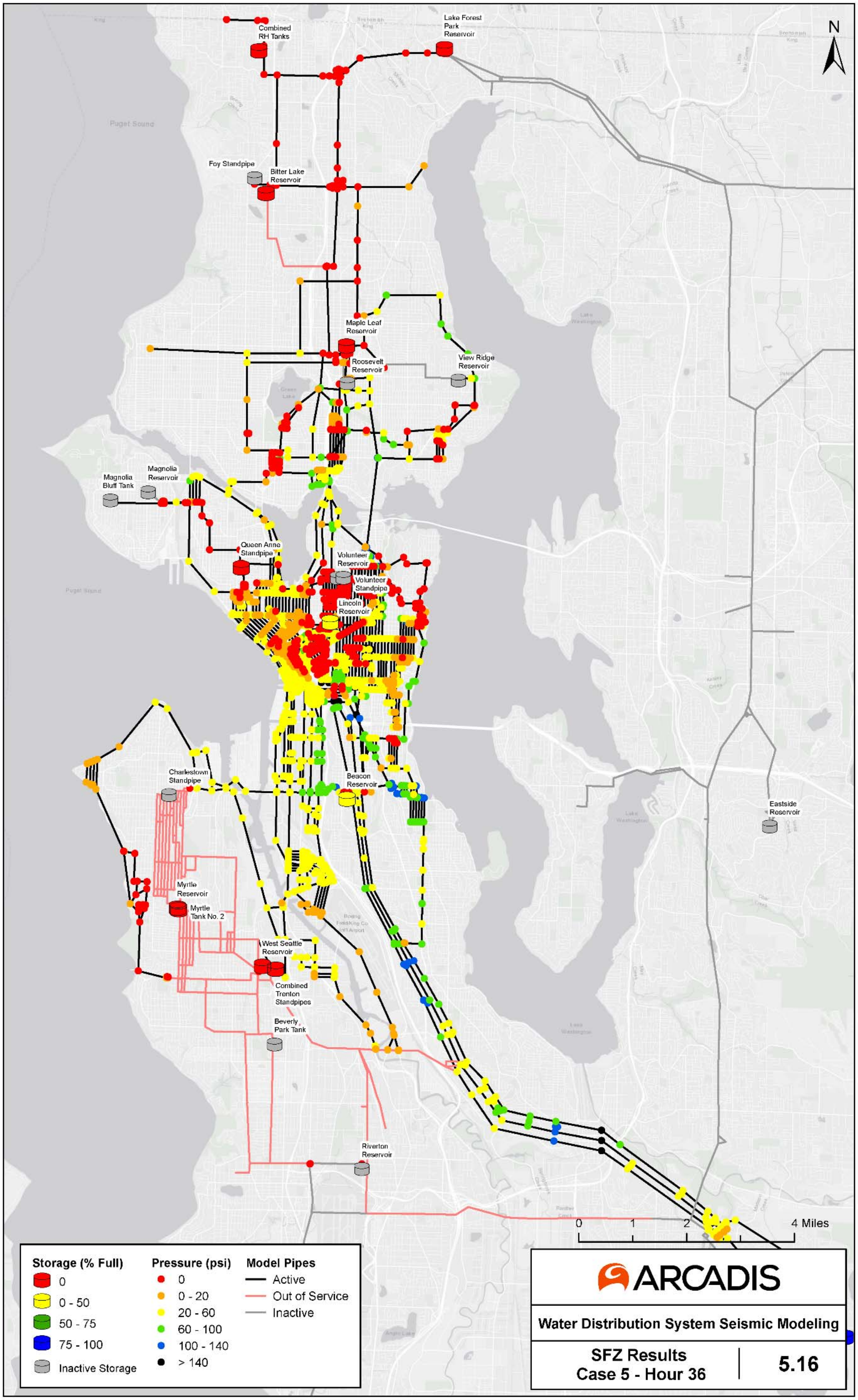
5.15



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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 5 - Hour 36
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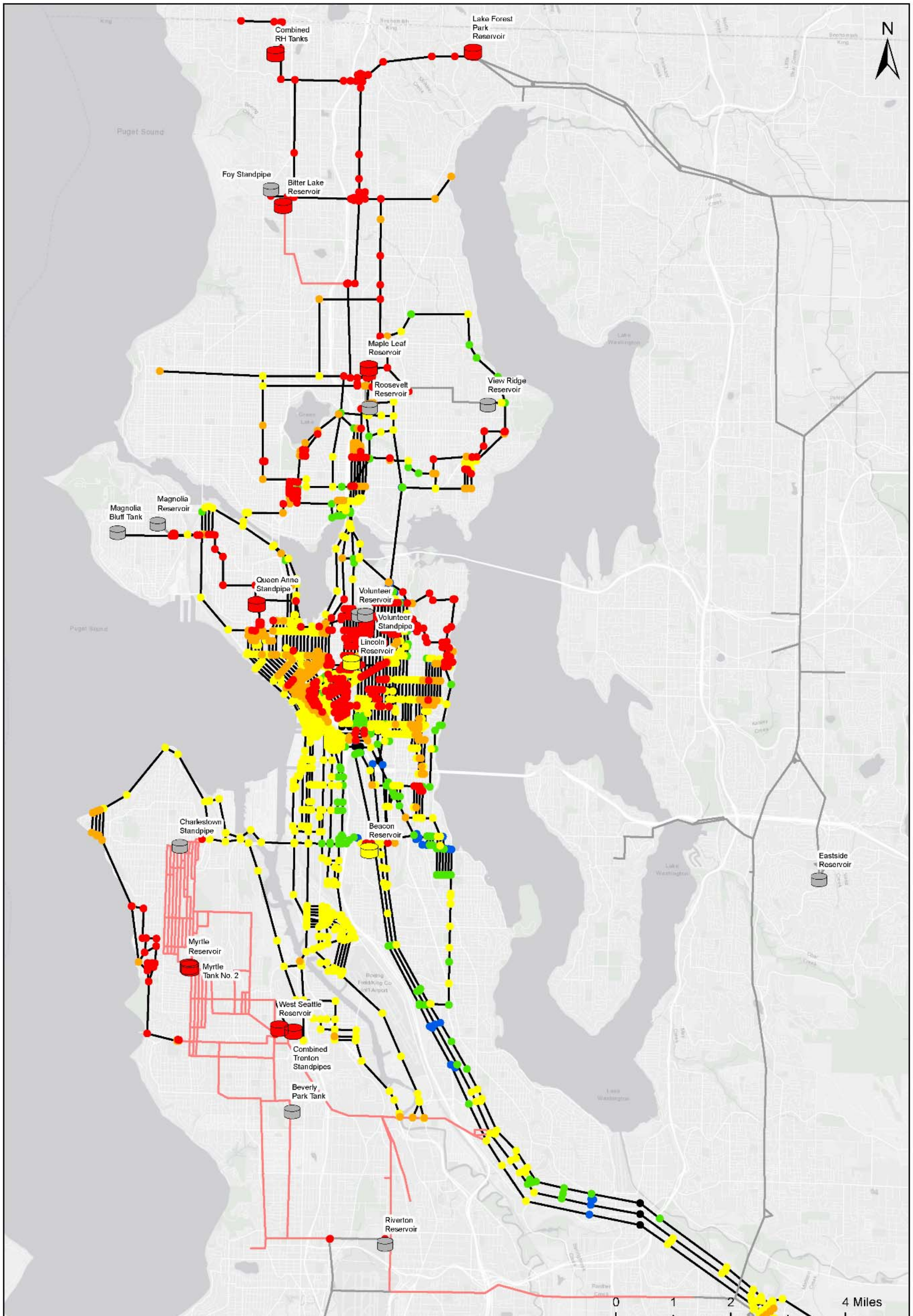

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Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 40

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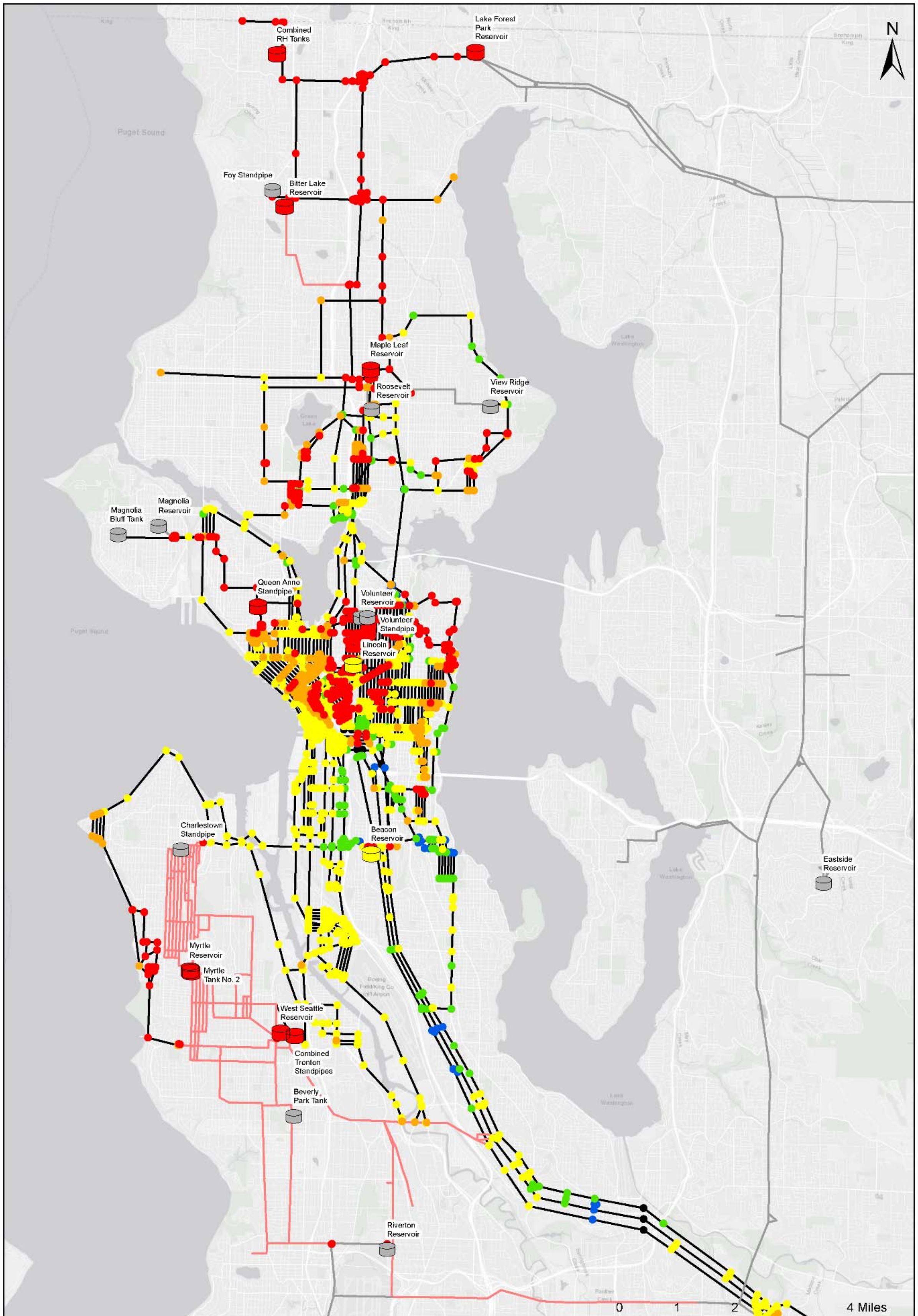

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Water Distribution System Seismic Modeling

SFZ Results
Case 5 - Hour 44

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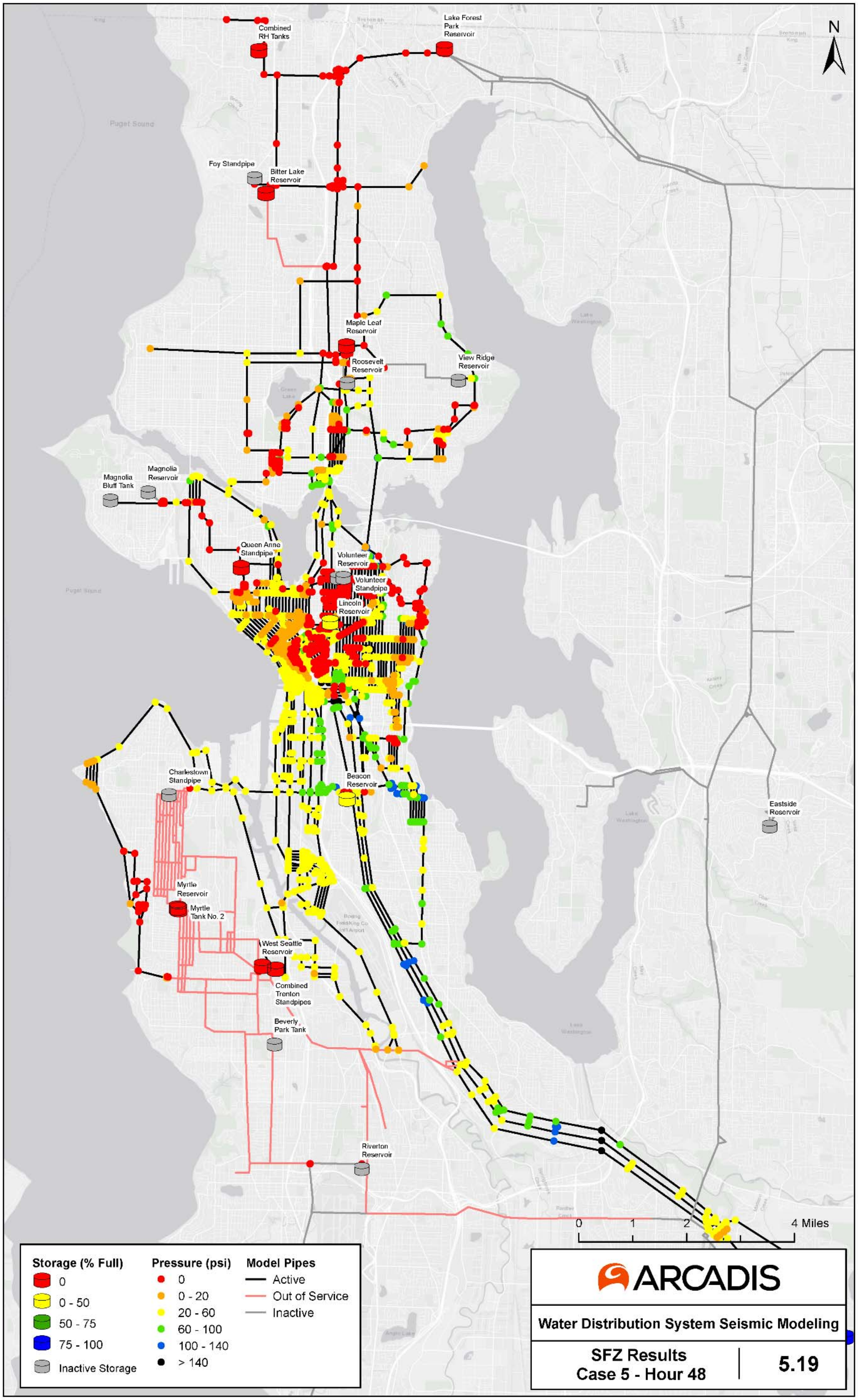

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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 5 - Hour 48
5.19

M7.0 Seattle Fault Zone Case 6 (No Improvements Except Cedar Transmission System is Assumed to be Functional and Damage Isolation Systems Have Been Installed) Hydraulic Modeling Results

ARCADIS | Design & Consultancy for natural and built assets
Water Distribution System Seismic Modeling
2/2/2018

Seattle Fault Seismic Event

Case 6 Same as Case 5

Assume that certain emitters are now zero and that certain areas are automatically isolated to prevent leakage

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	145,539	121,380	24,159	88%	232.1
3	142,811	118,735	24,076	88%	217.3
12	126,254	107,476	18,778	75%	182.6
22	120,986	102,368	18,618	73%	149.1
32	120,437	101,820	18,618	73%	119.2
48	100,569	82,773	17,796	70%	85.2

Model Regions Forced Out of Service During Simulation

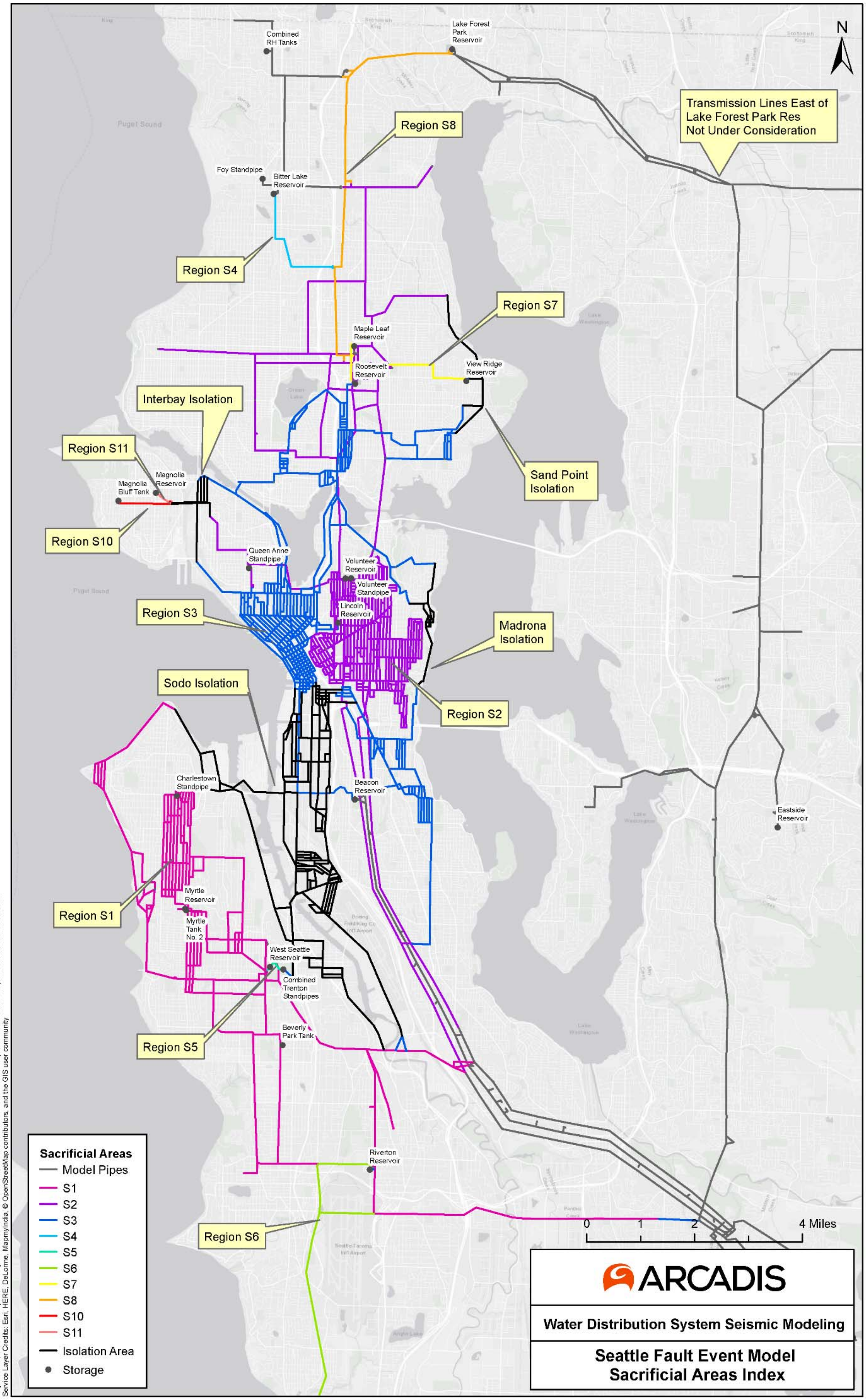
Time	Region
6	S1
38	S8

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 6.1	Hr 0	Fig. 6.5	Hr 8	Fig. 6.9	Hr 16	Fig. 6.13	Hr 24	Fig. 6.17	Hr 40
Fig. 6.2	Hr 2	Fig. 6.6	Hr 10	Fig. 6.10	Hr 18	Fig. 6.14	Hr 28	Fig. 6.18	Hr 44
Fig. 6.3	Hr 4	Fig. 6.7	Hr 12	Fig. 6.11	Hr 20	Fig. 6.15	Hr 32	Fig. 6.19	Hr 48
Fig. 6.4	Hr 6	Fig. 6.8	Hr 14	Fig. 6.12	Hr 22	Fig. 6.16	Hr 36		



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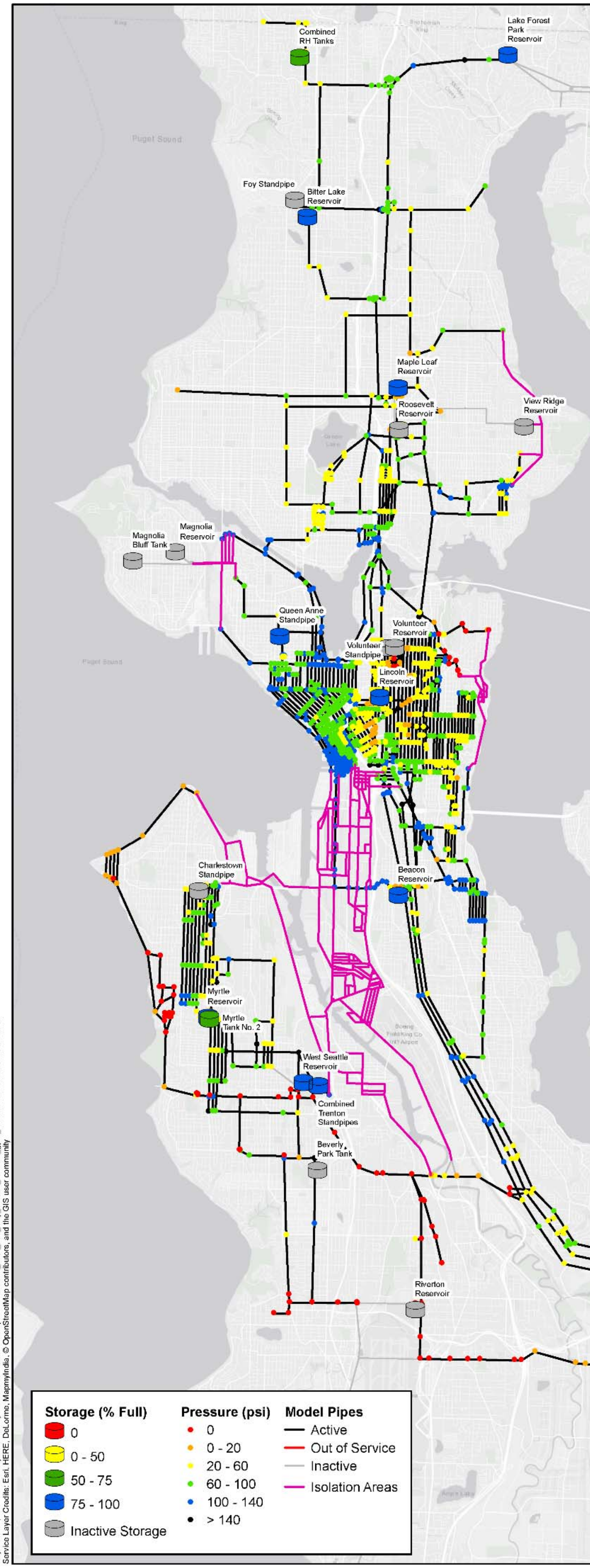

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Water Distribution System Seismic Modeling

SFZ Results
Case 6 - Hour 0

6.1

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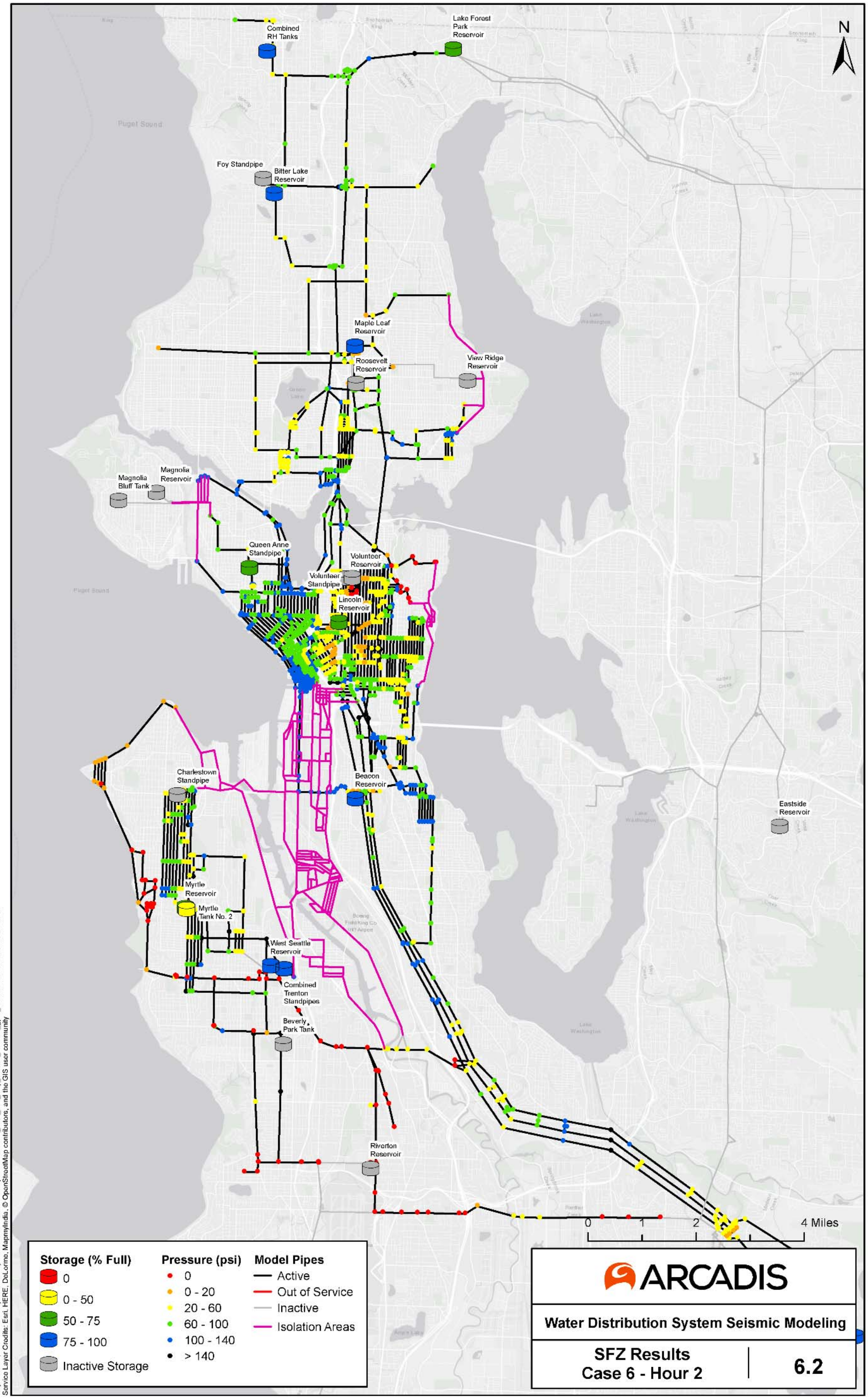

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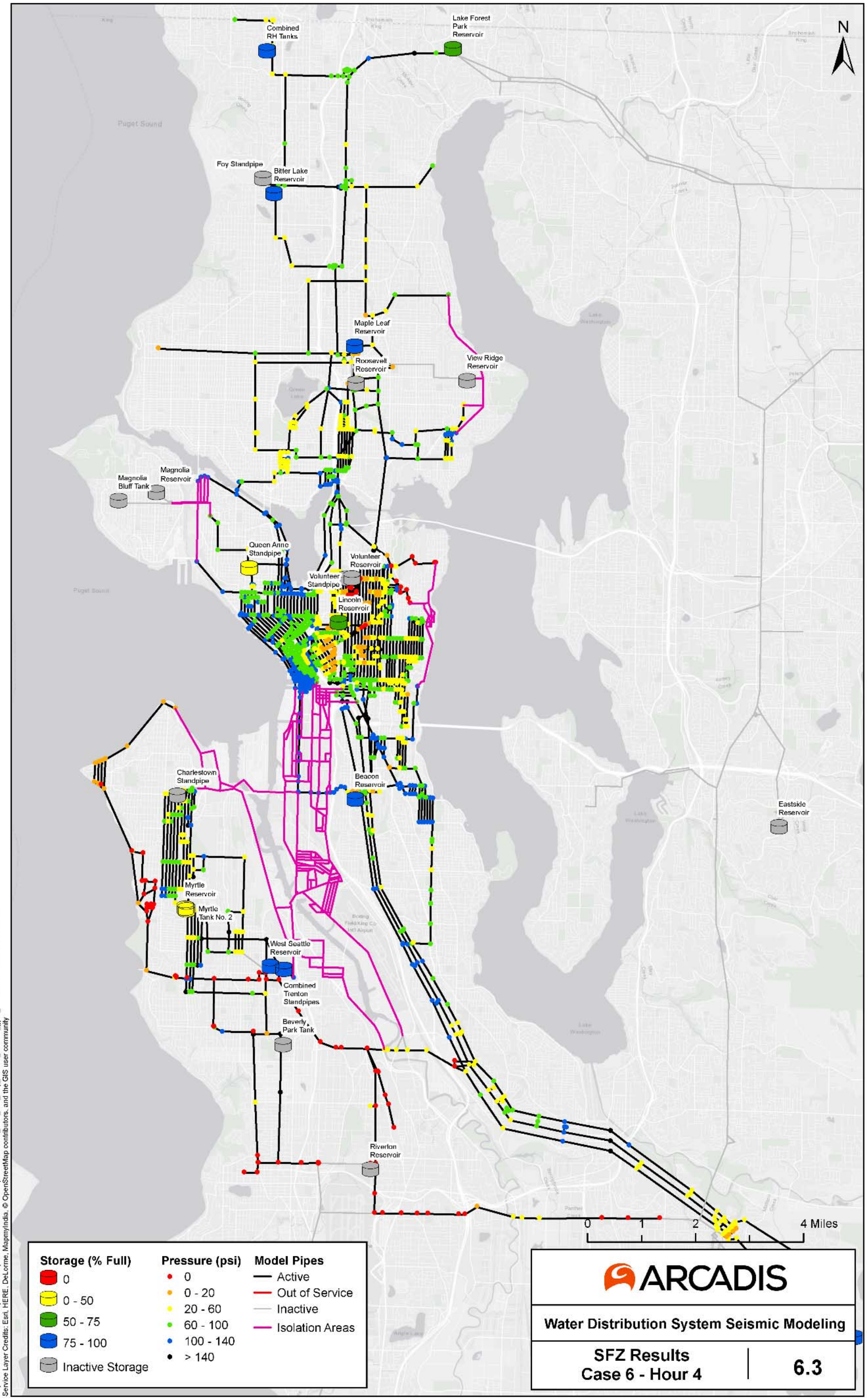

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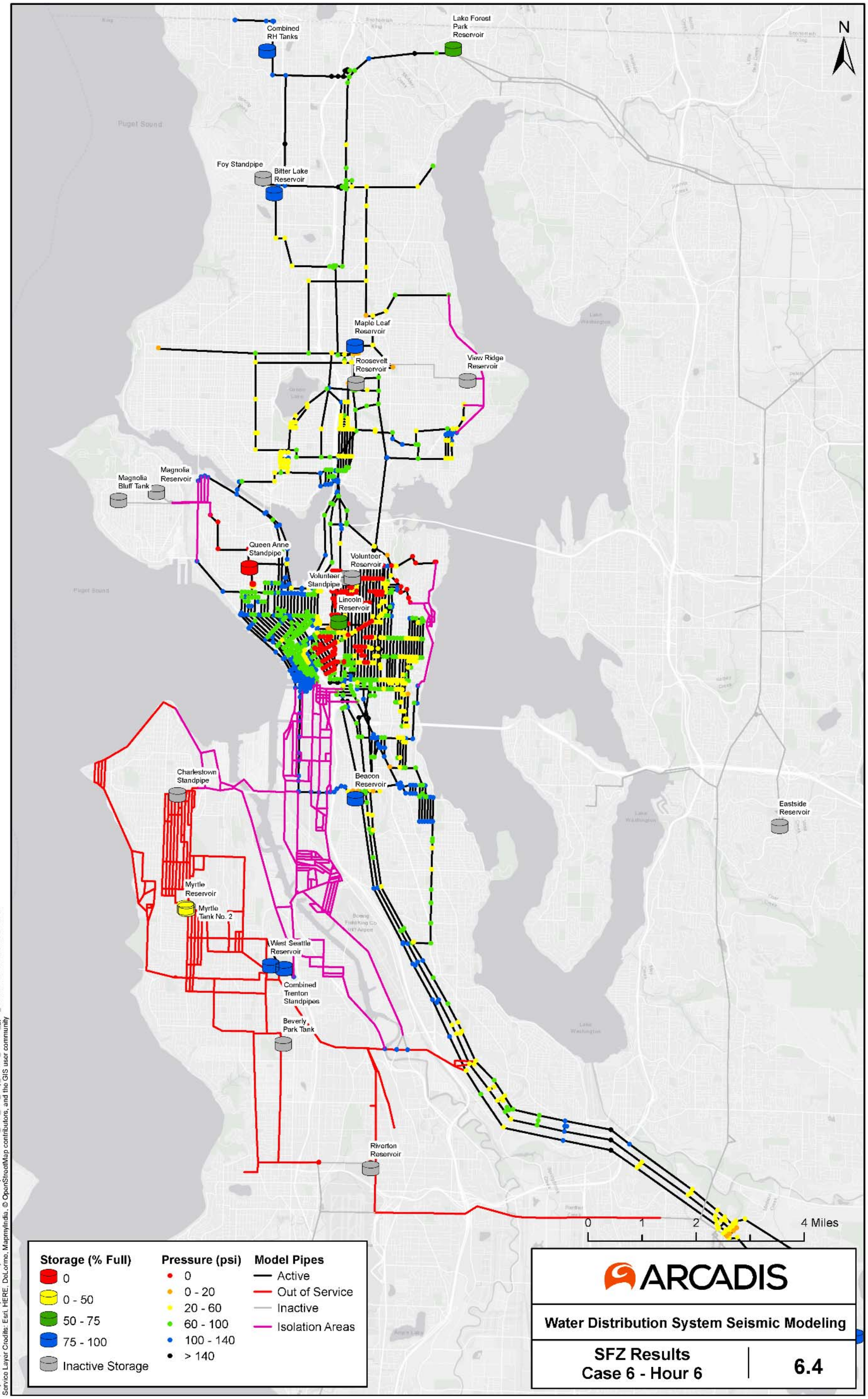

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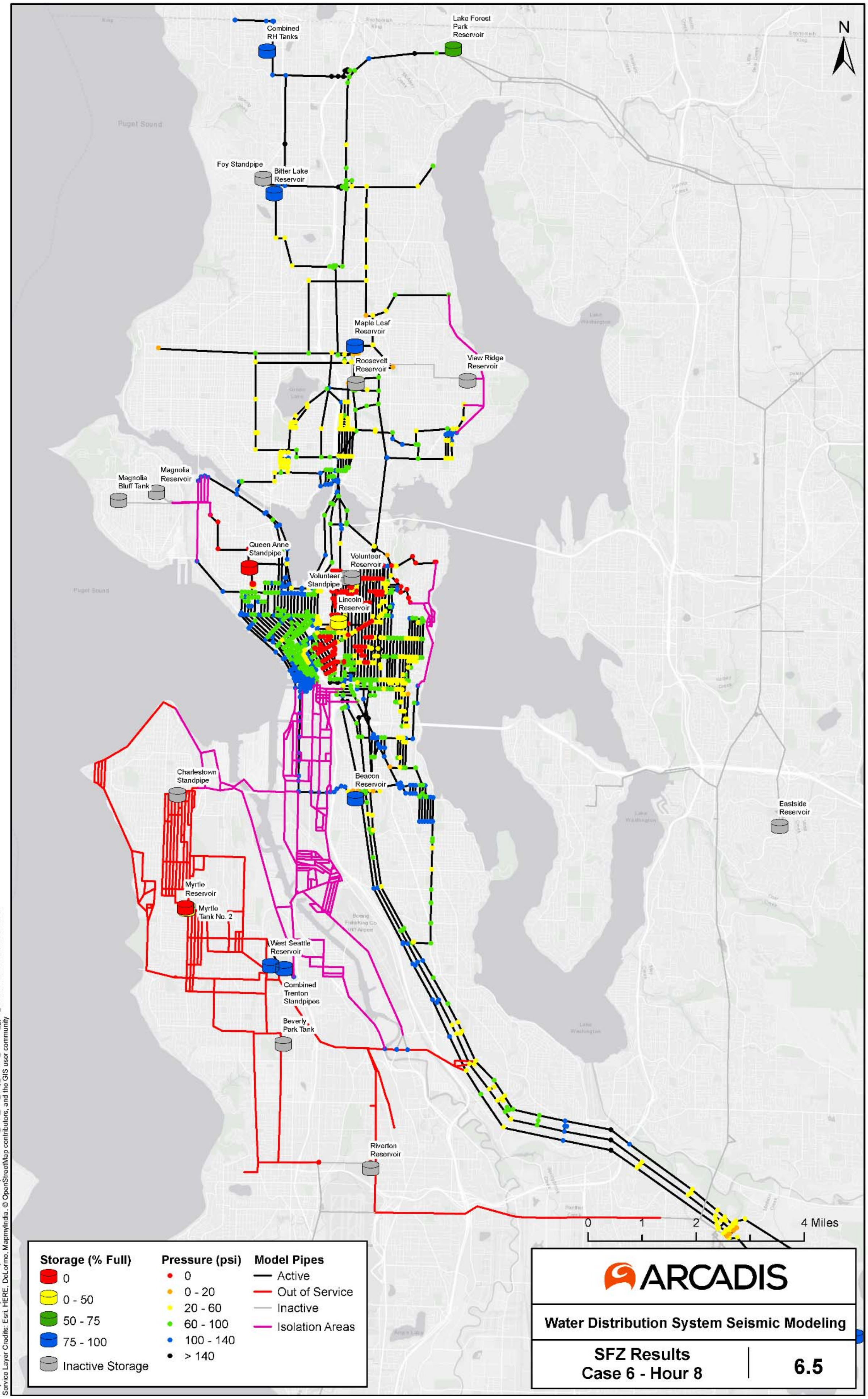

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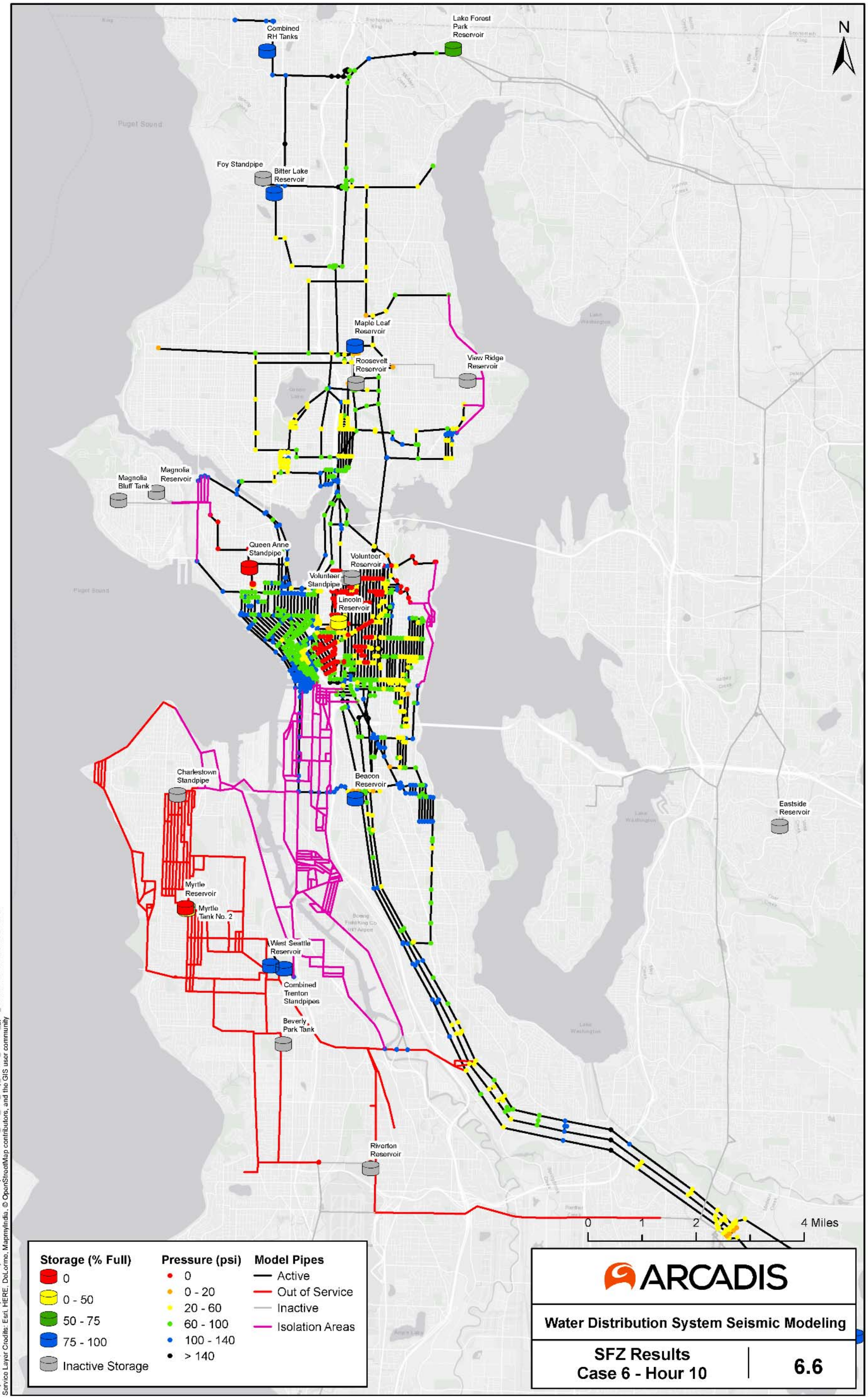

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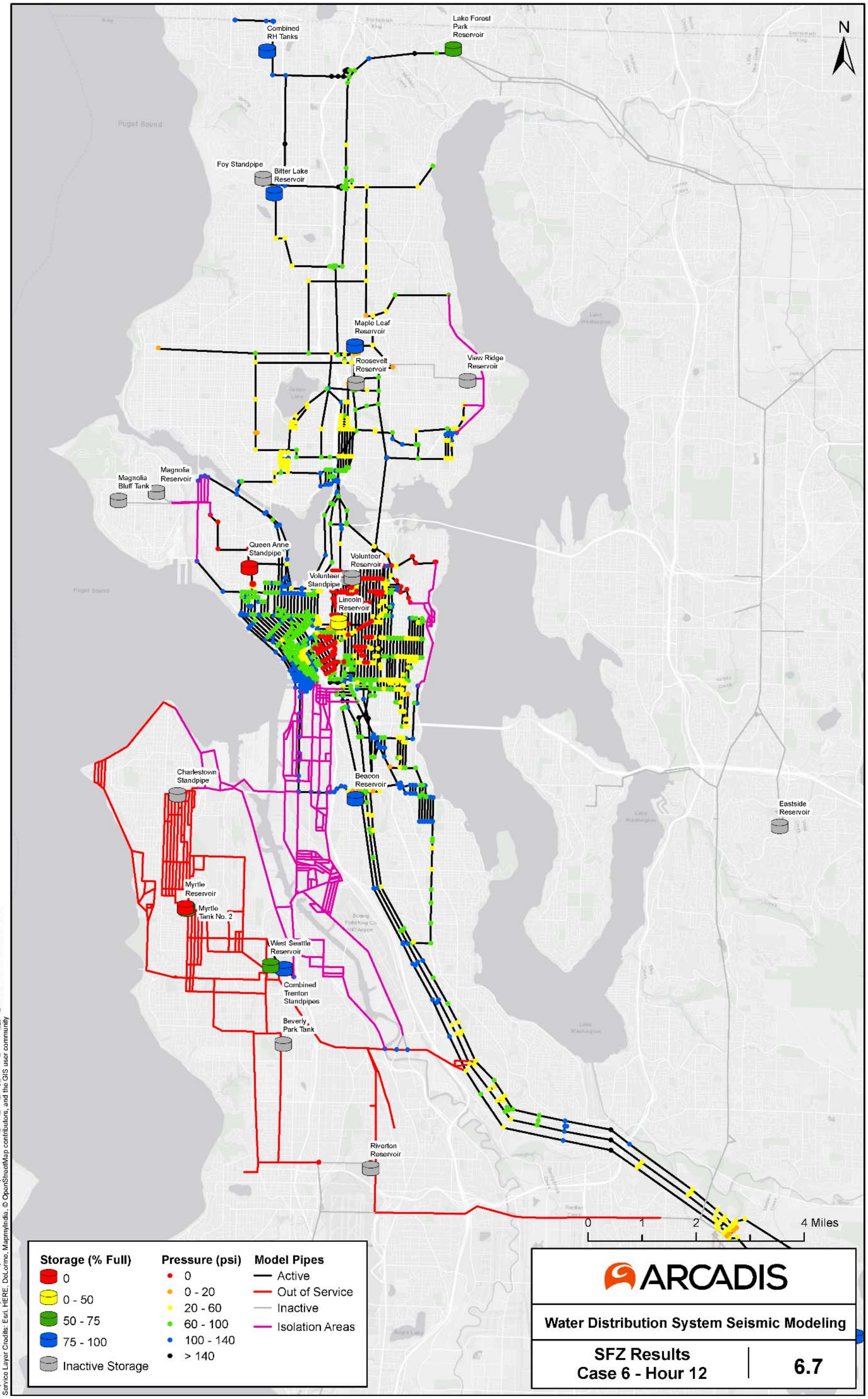

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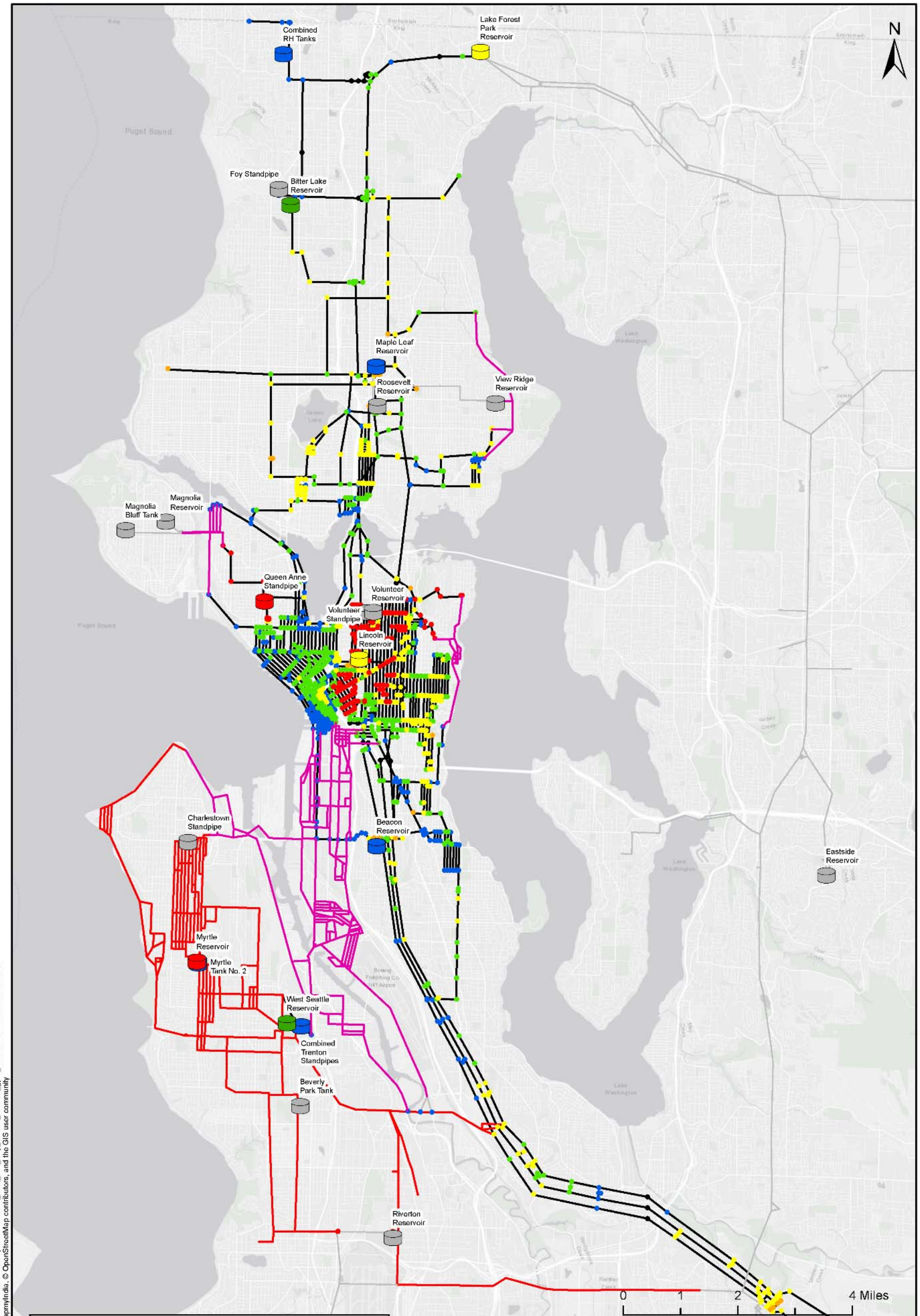

ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 6 - Hour 14

6.8

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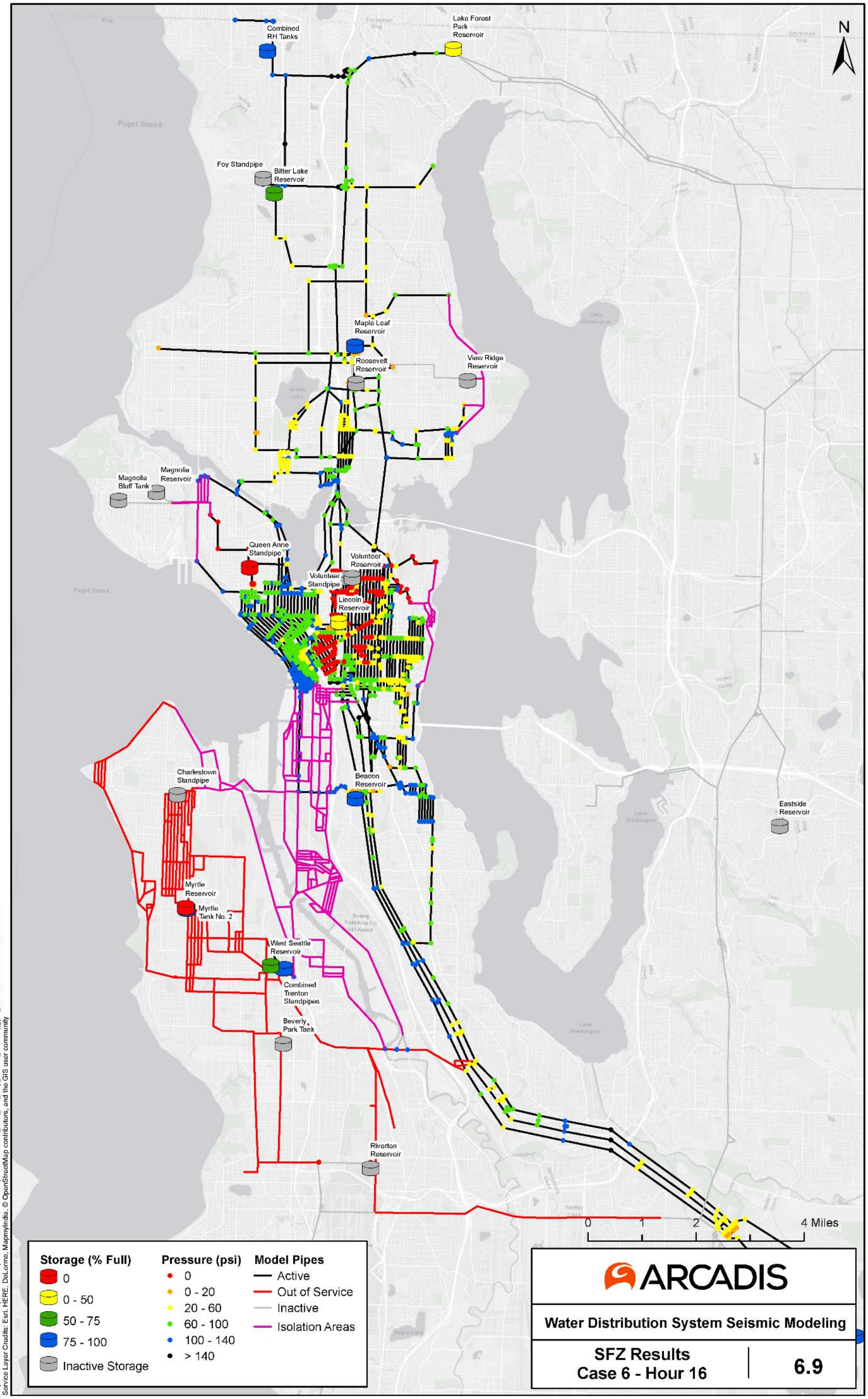

ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 6 - Hour 16

6.9

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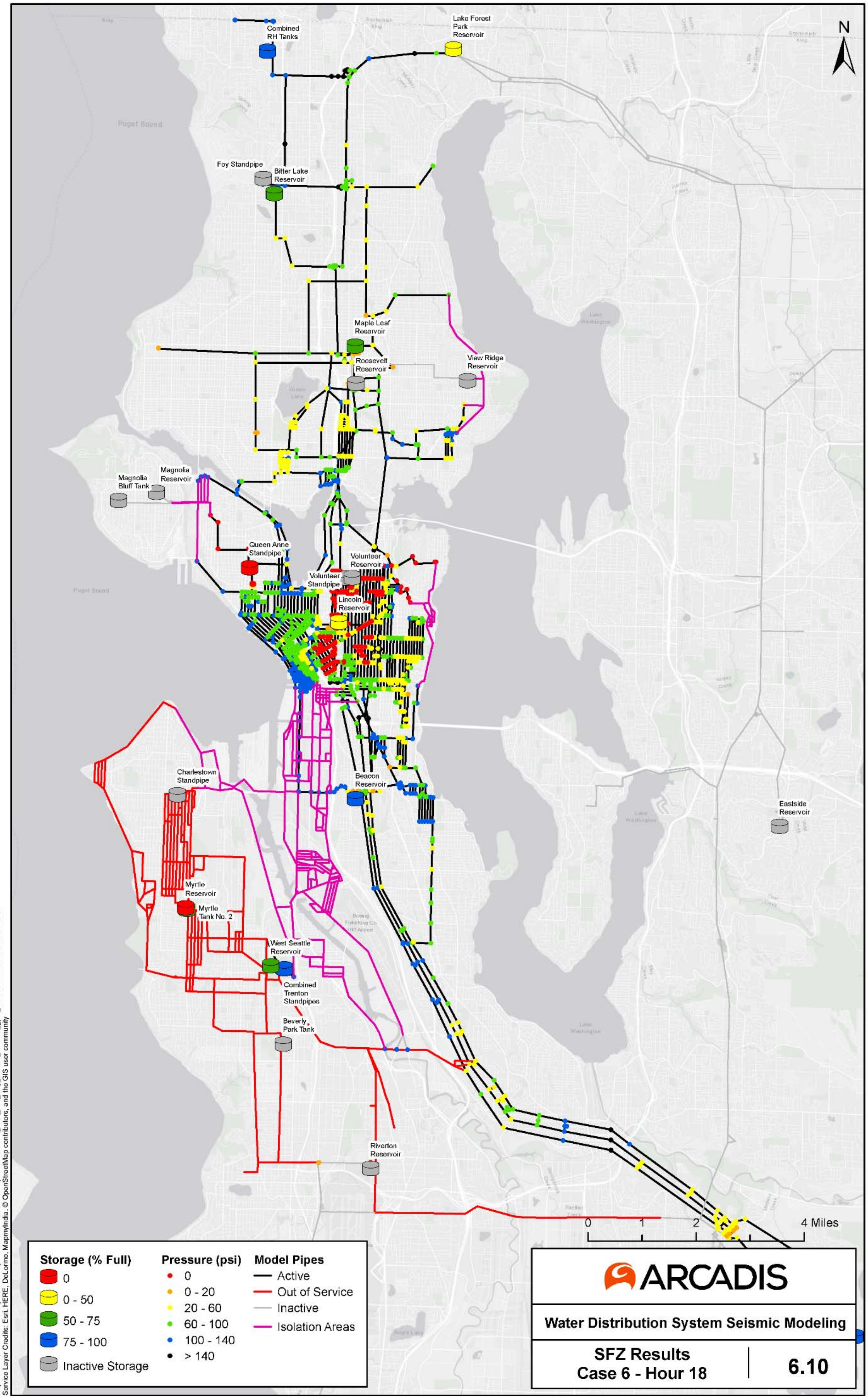
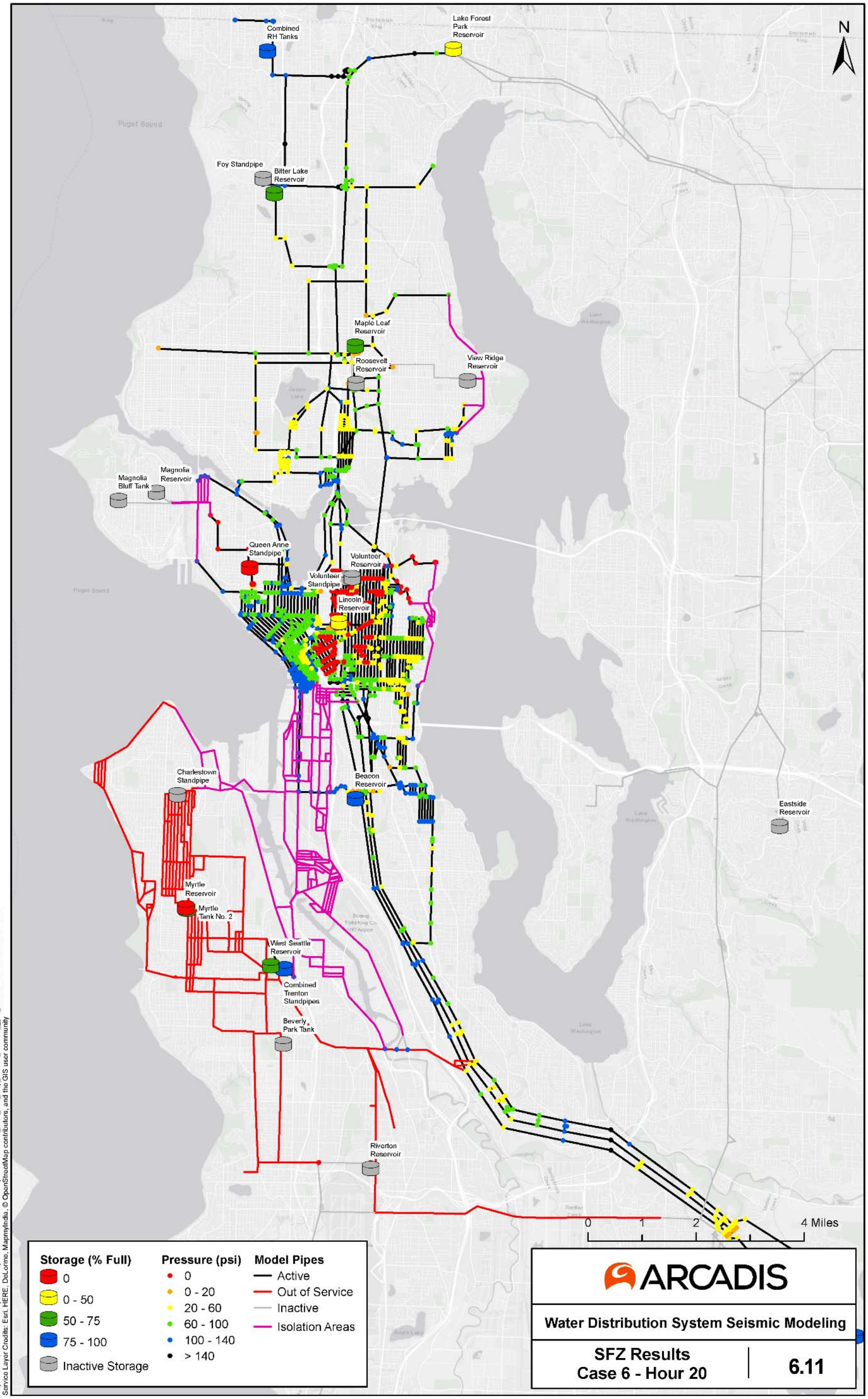

Combined RH Tanks
Lake Forest Park Reservoir
N
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
Water Distribution System Seismic Modeling
SFZ Results
Case 6 - Hour 18
6.10



Water Distribution System Seismic Modeling

SFZ Results
Case 6 - Hour 20

6.11

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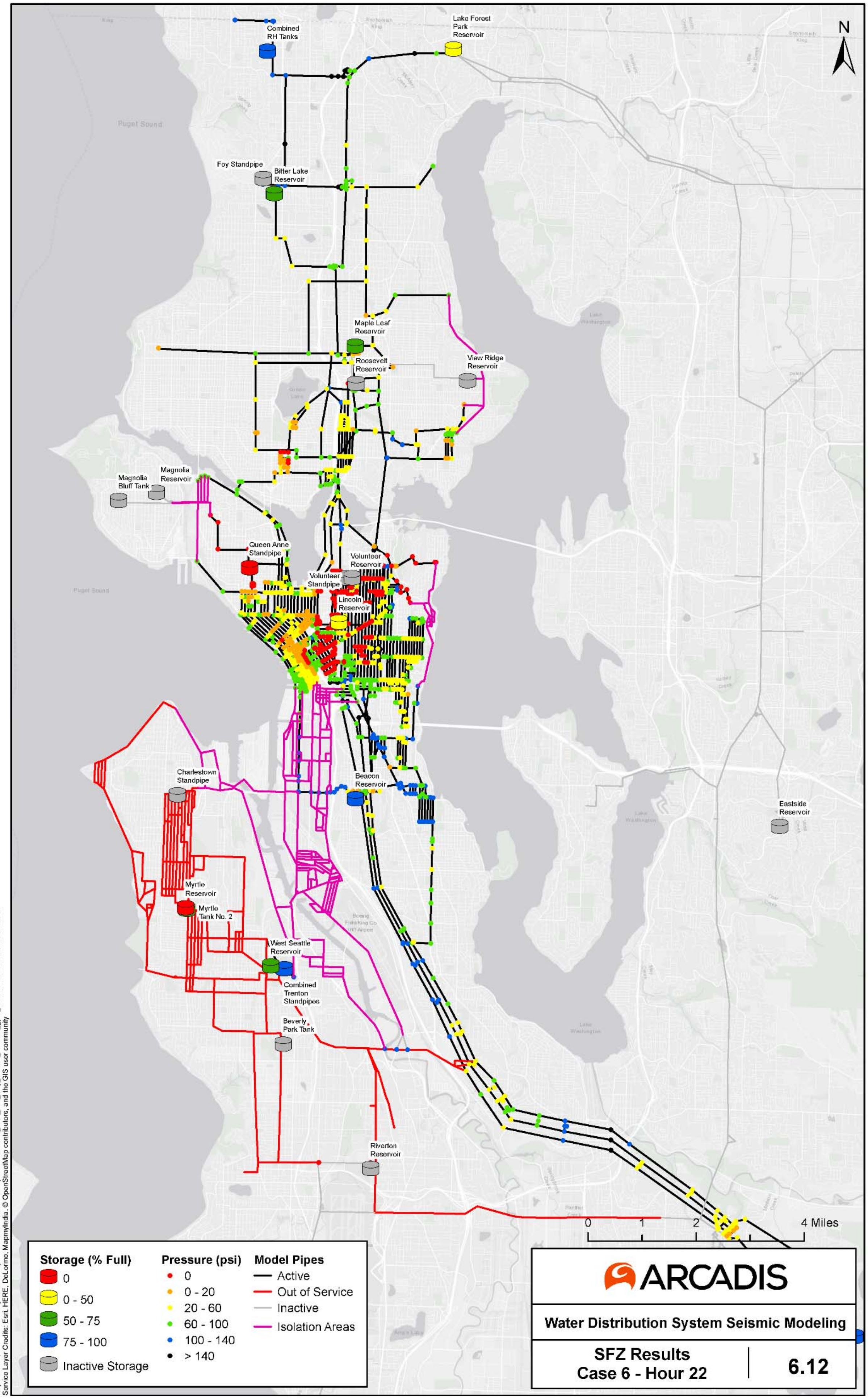

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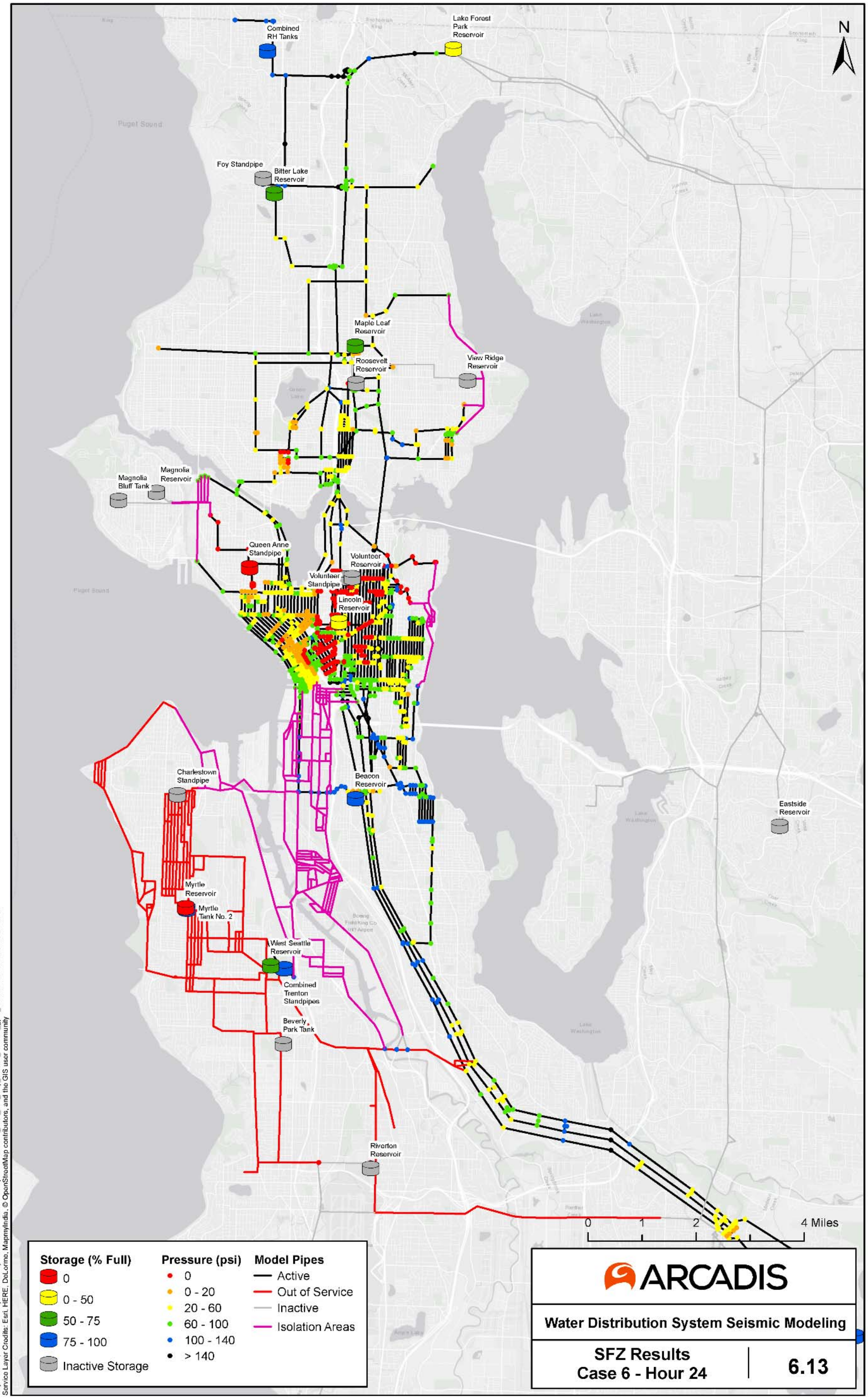

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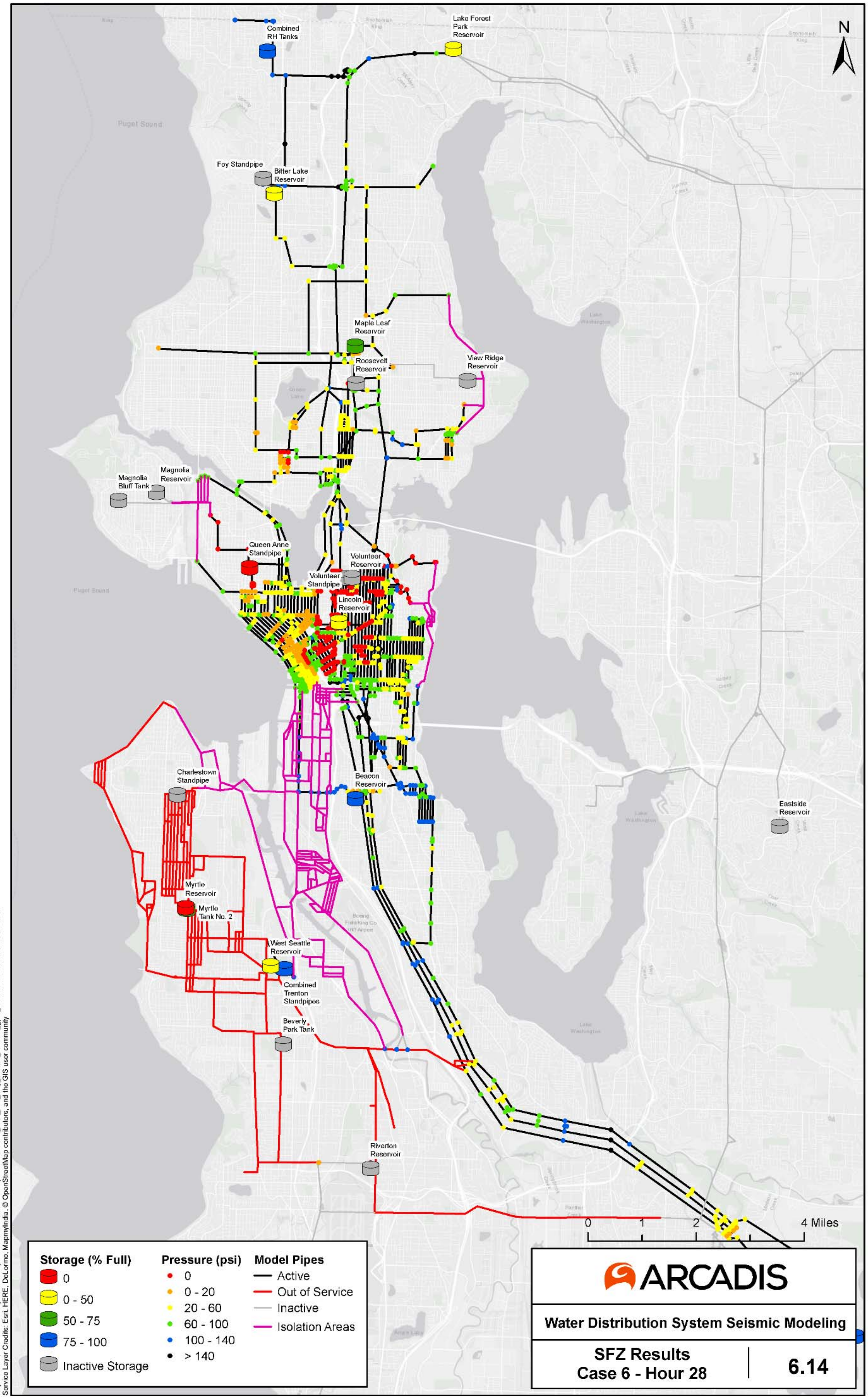

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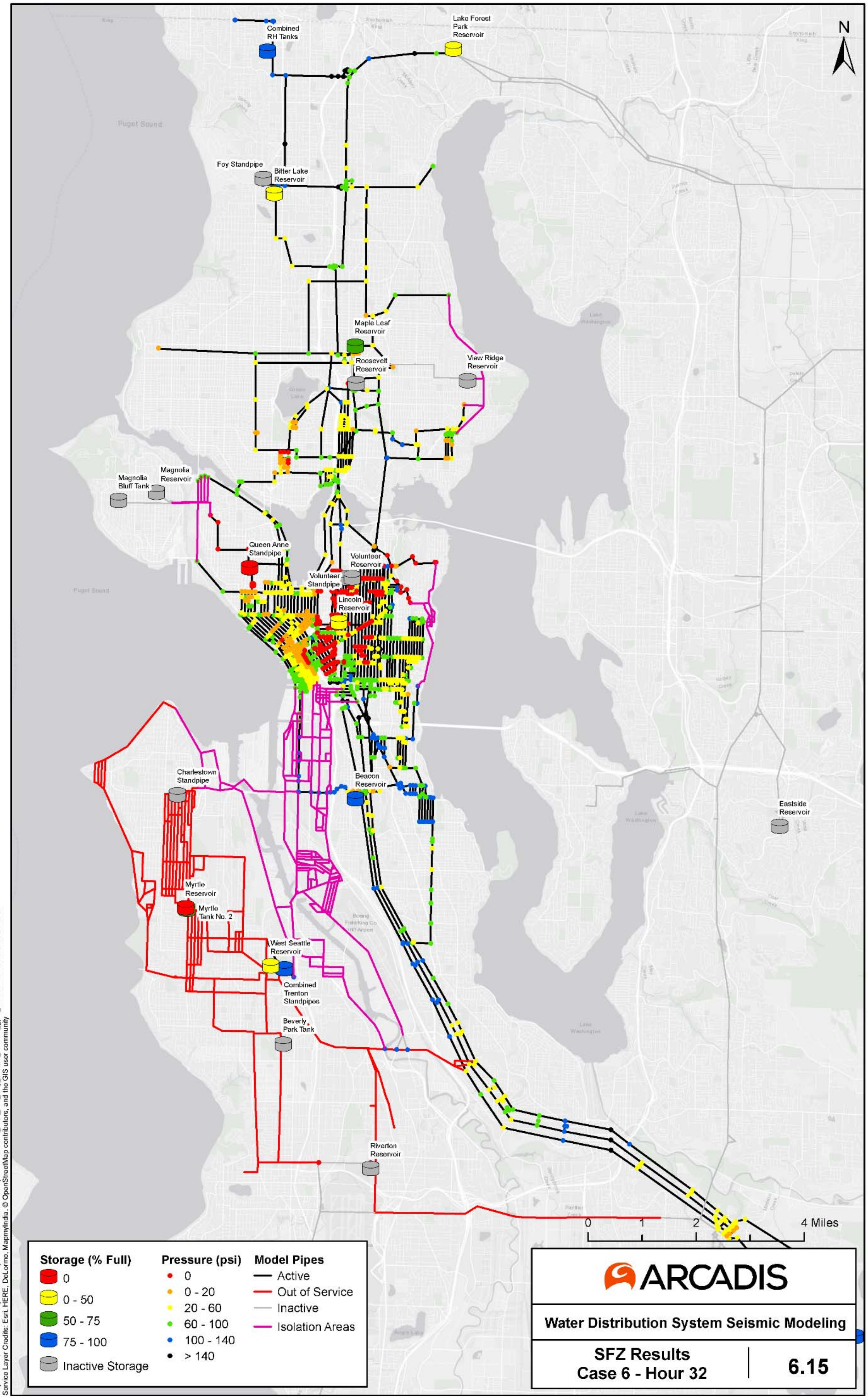

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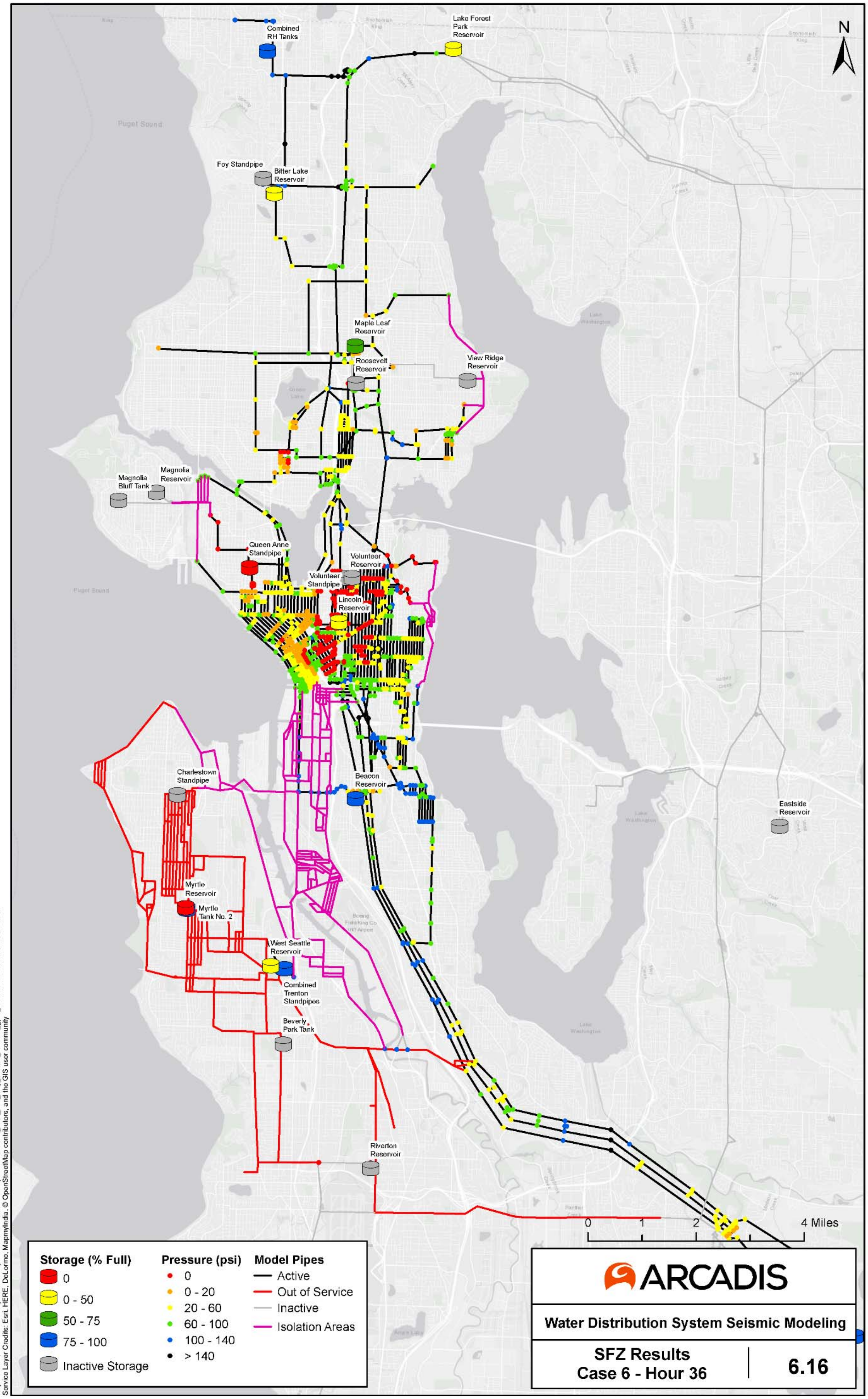

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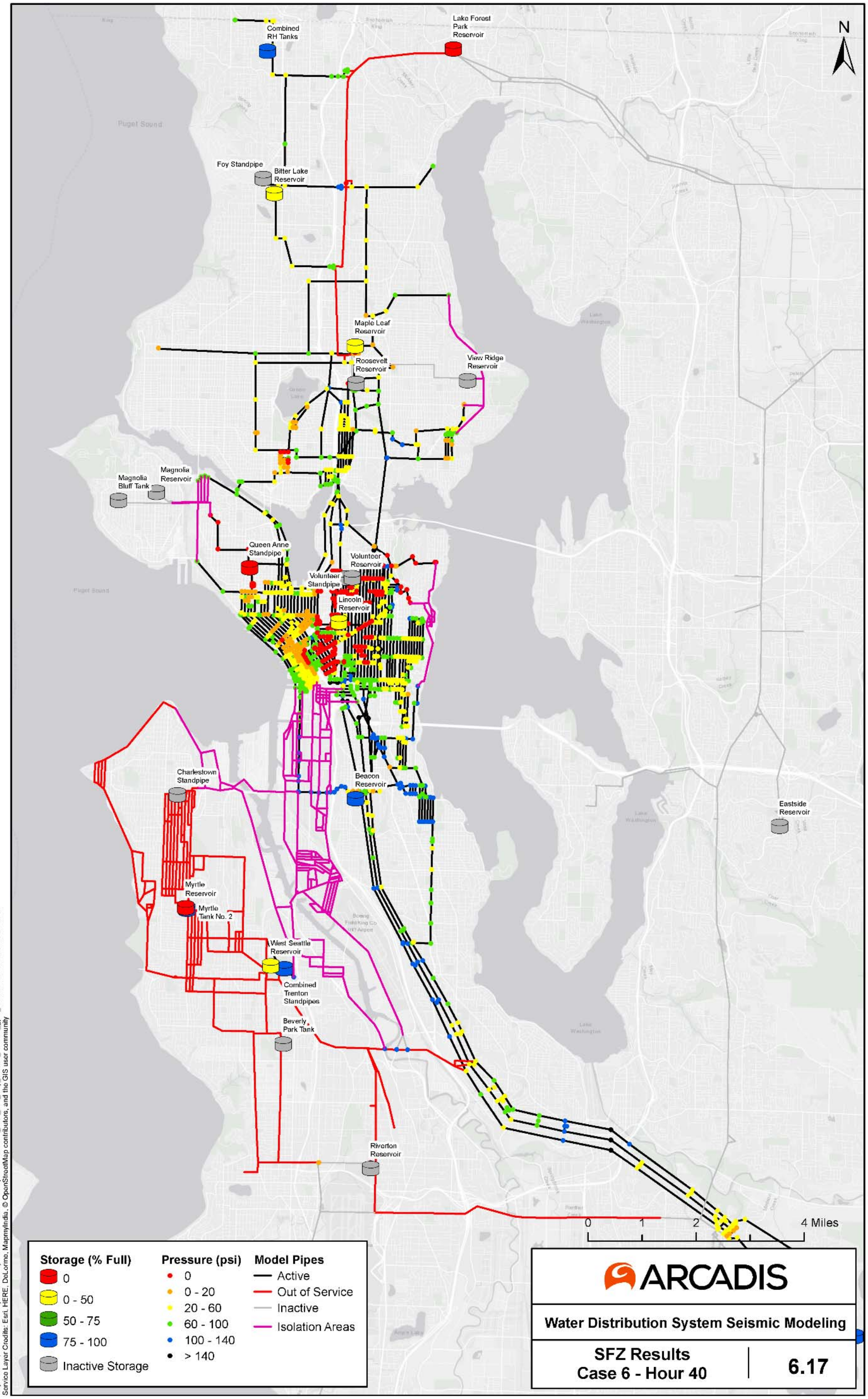

Water Distribution System Seismic Modeling

SFZ Results
Case 6 - Hour 40

6.17

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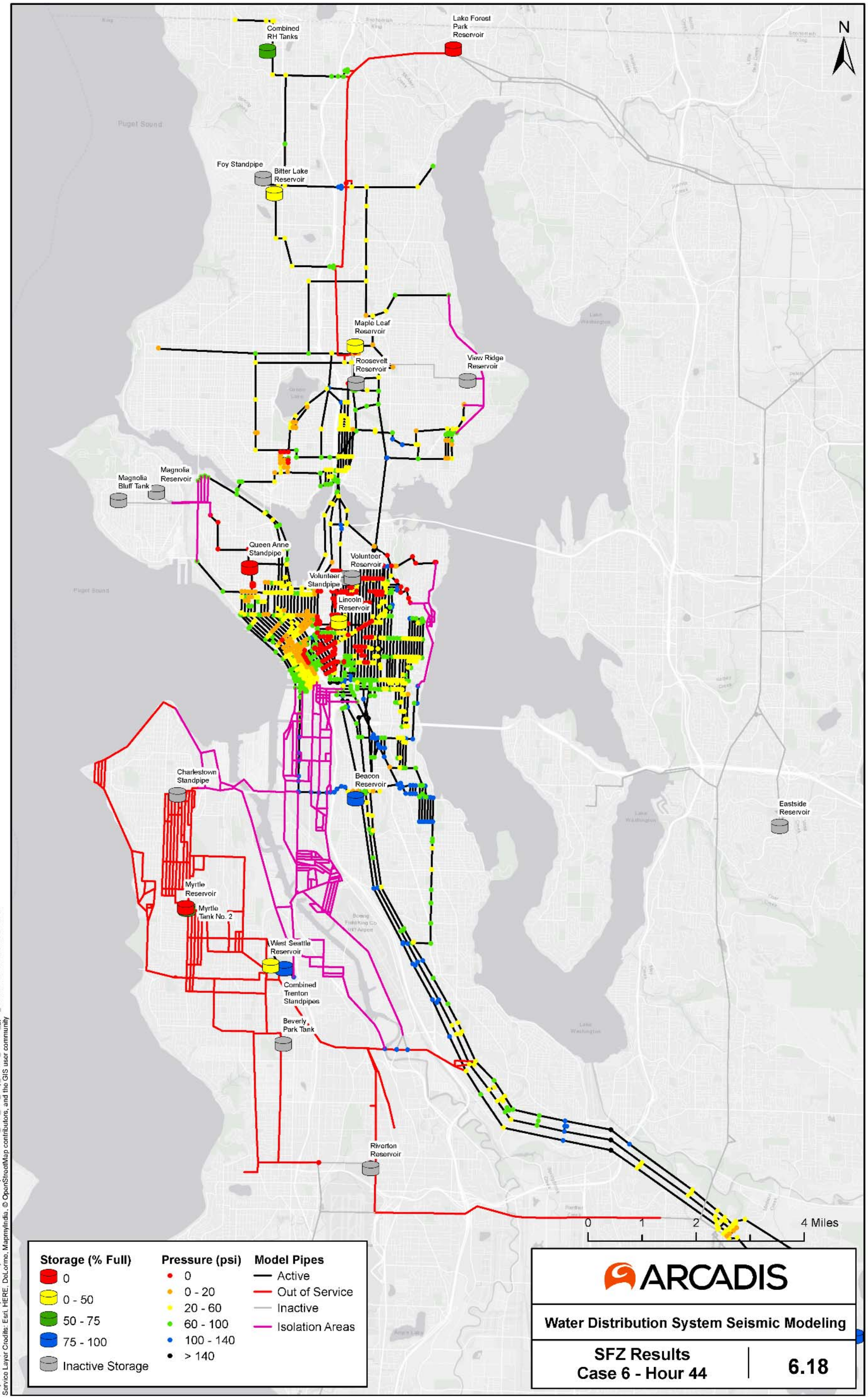

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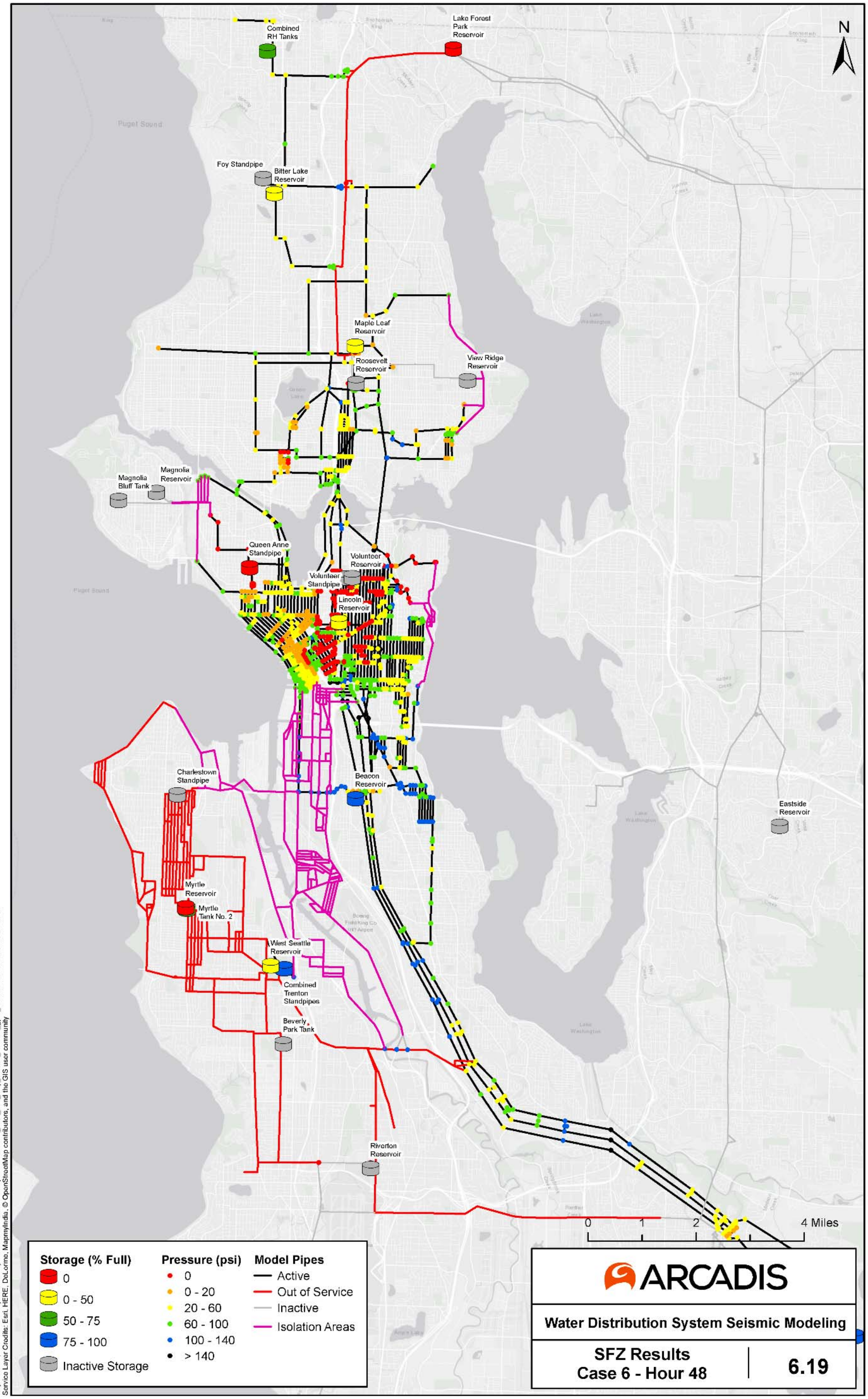

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M7.0 Seattle Fault Zone Case 7 (No Improvements Except Tolt Transmission System is Assumed to be Functional) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/6/2018

Seattle Fault Seismic Event

Case 7 Same as "Base" case

Tolt Pipelines are Functional

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	250,512	230,344	20,168	71%	232.1
3	228,068	211,560	16,508	60%	188.7
12	178,531	164,405	14,126	45%	87.1
22	53,577	49,897	3,680	7%	34.4
32	50,317	47,371	2,946	5%	4.1
48	39,050	36,105	2,946	5%	1.0

Model Regions Forced Out of Service During Simulation

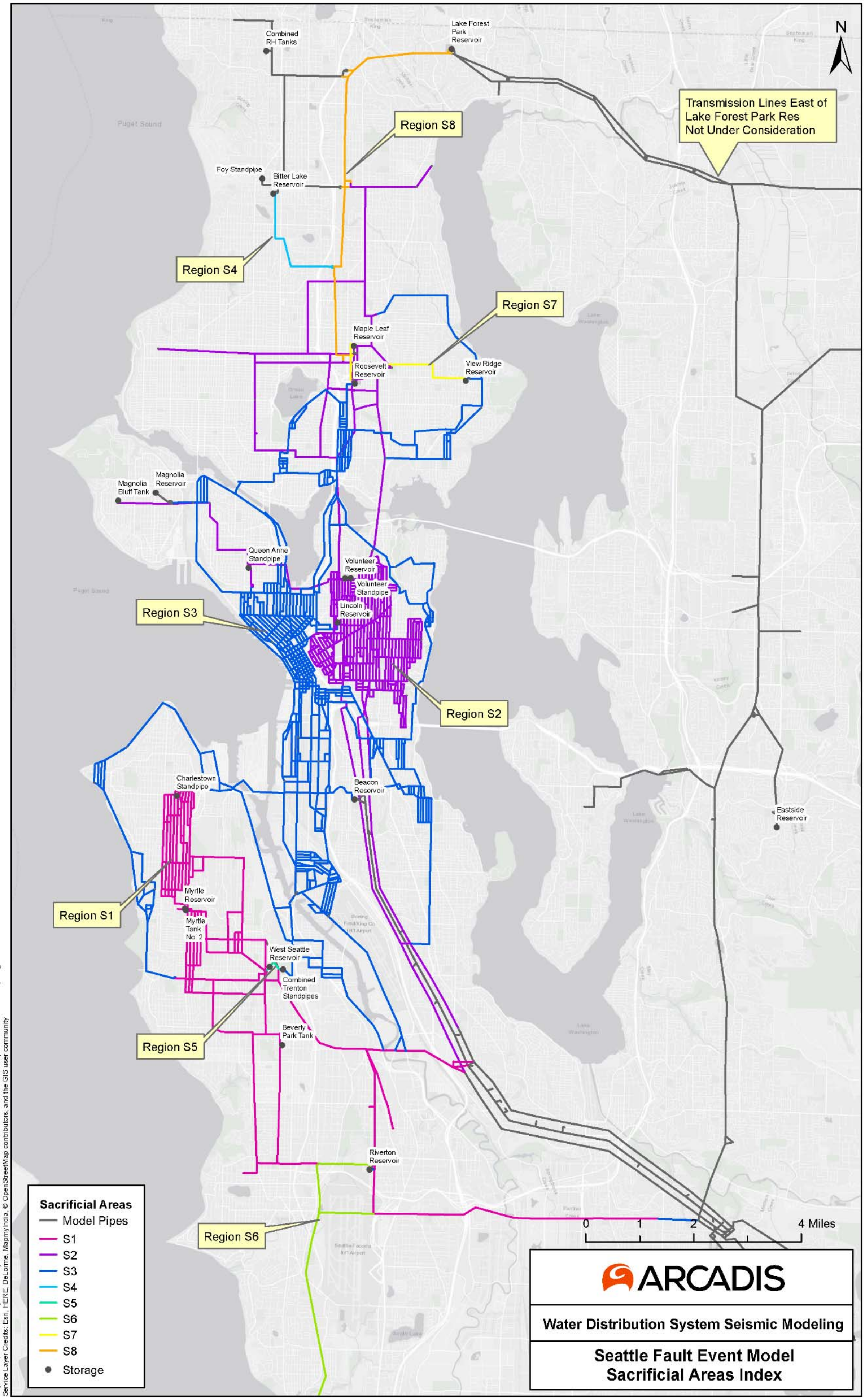
Time	Region
3	S1
15	S2
32	S4
34	S3

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 7.1	Hr 0	Fig. 7.5	Hr 8	Fig. 7.9	Hr 16	Fig. 7.13	Hr 24	Fig. 7.17	Hr 40
Fig. 7.2	Hr 2	Fig. 7.6	Hr 10	Fig. 7.10	Hr 18	Fig. 7.14	Hr 28	Fig. 7.18	Hr 44
Fig. 7.3	Hr 4	Fig. 7.7	Hr 12	Fig. 7.11	Hr 20	Fig. 7.15	Hr 32	Fig. 7.19	Hr 48
Fig. 7.4	Hr 6	Fig. 7.8	Hr 14	Fig. 7.12	Hr 22	Fig. 7.16	Hr 36		



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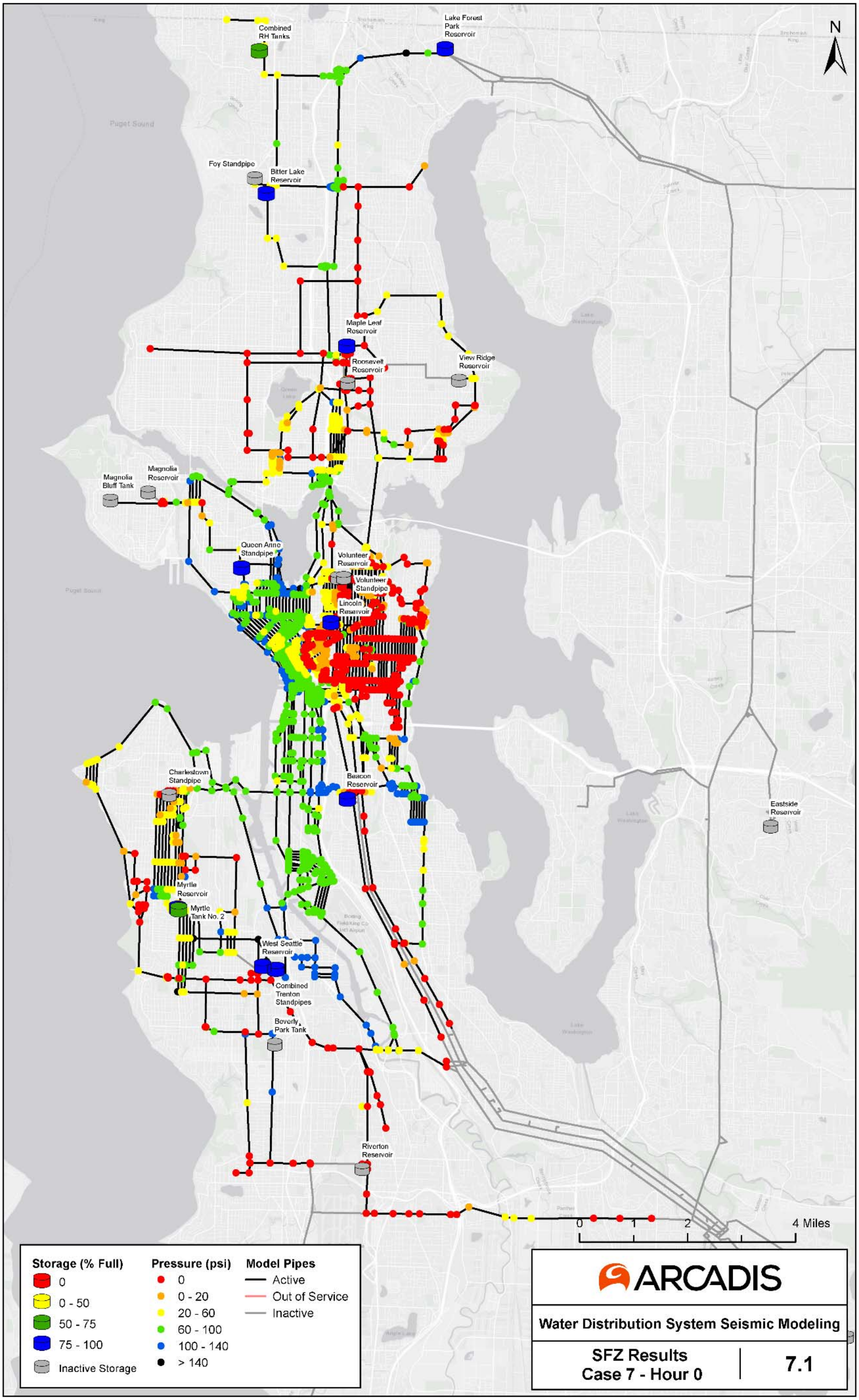
Combined RH Tanks
Lake Forest Park Reservoir
N
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
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Charlestown Standpipe
Beacon Reservoir
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Myrtle Reservoir
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West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
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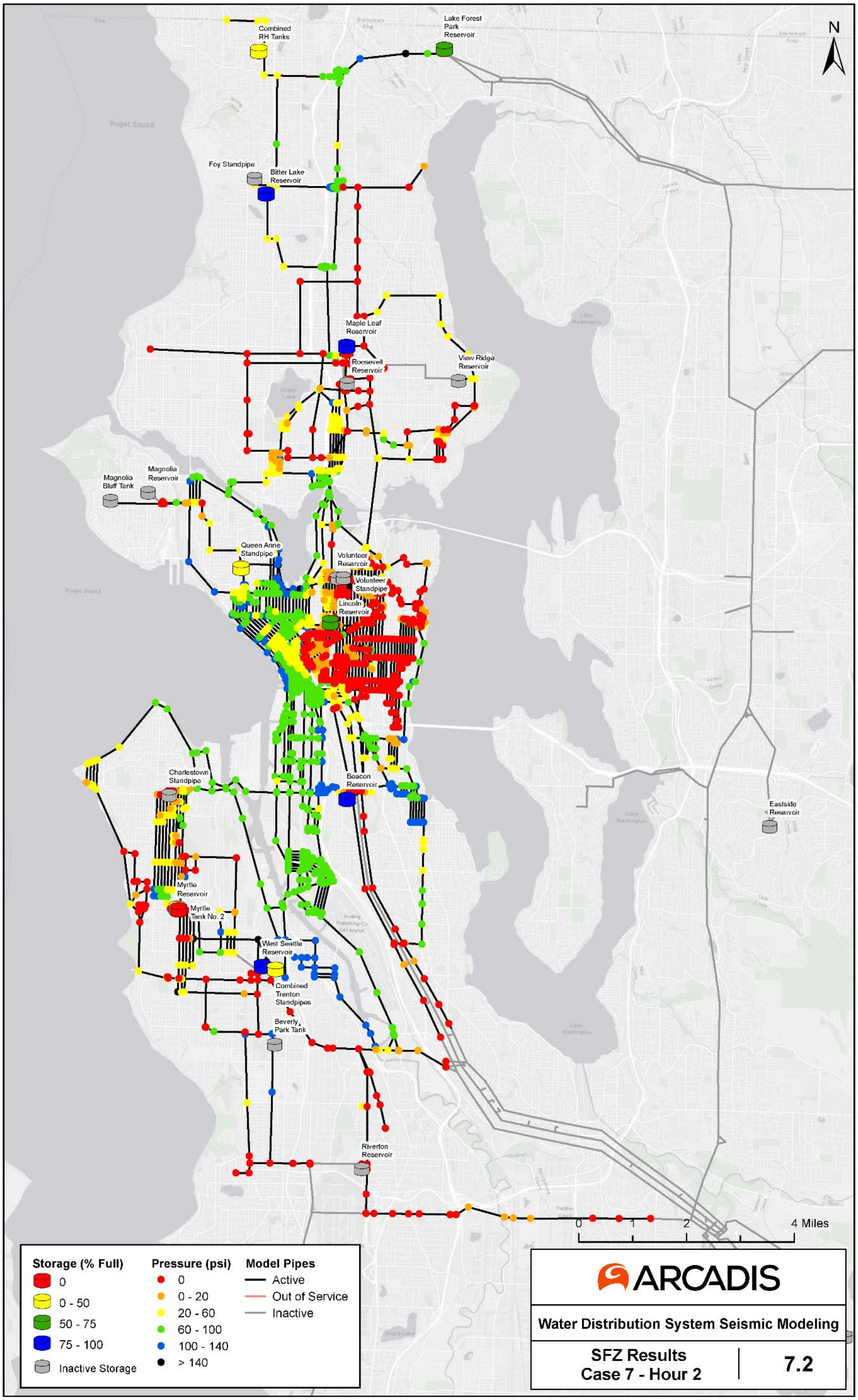
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 0
7.1

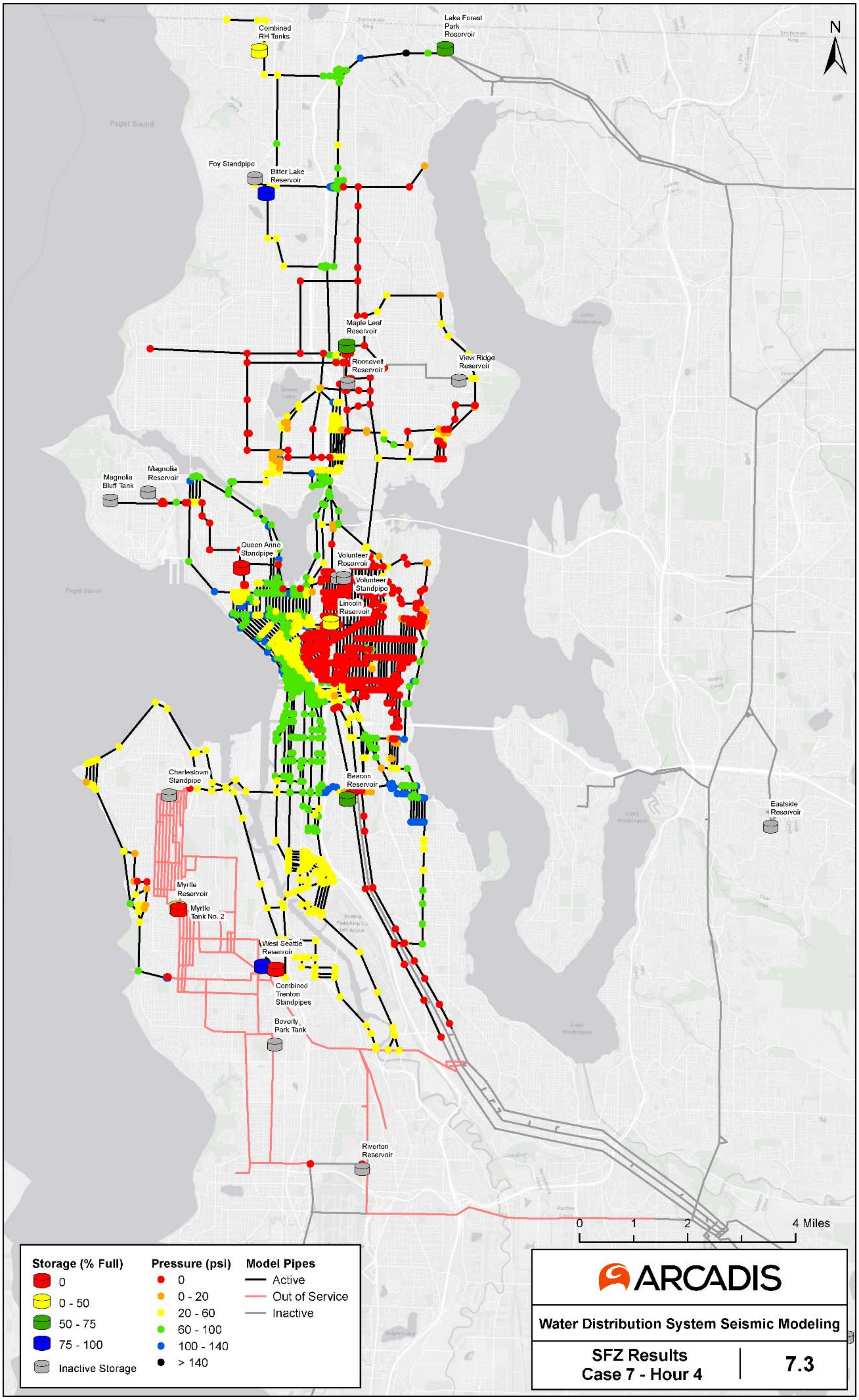


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 2

7.2



N
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
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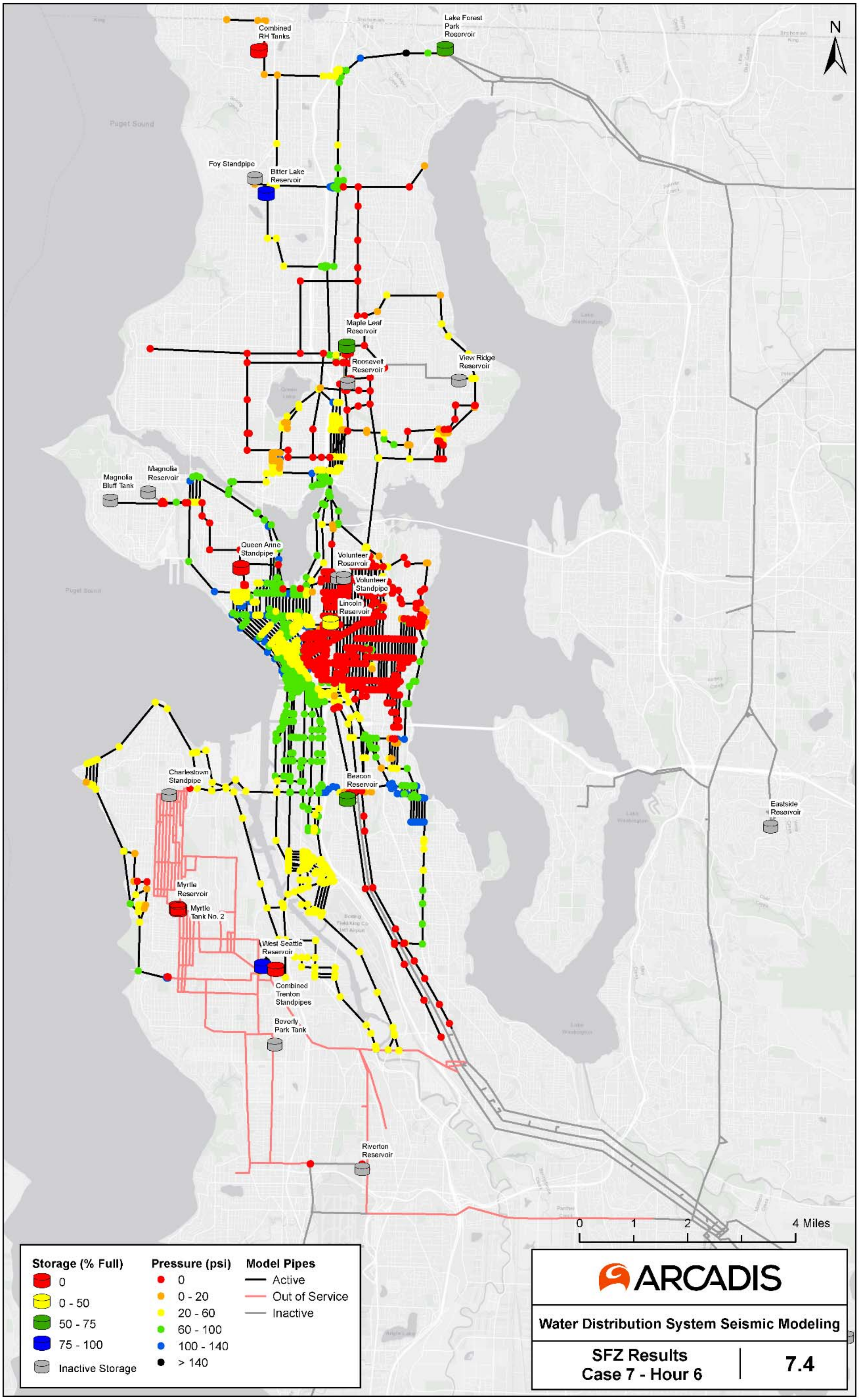
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 4
7.3


Combined RH Tanks
Lake Forest Park Reservoir
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Puget Sound
Foy Standpipe
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Inactive Storage
Pressure (psi)
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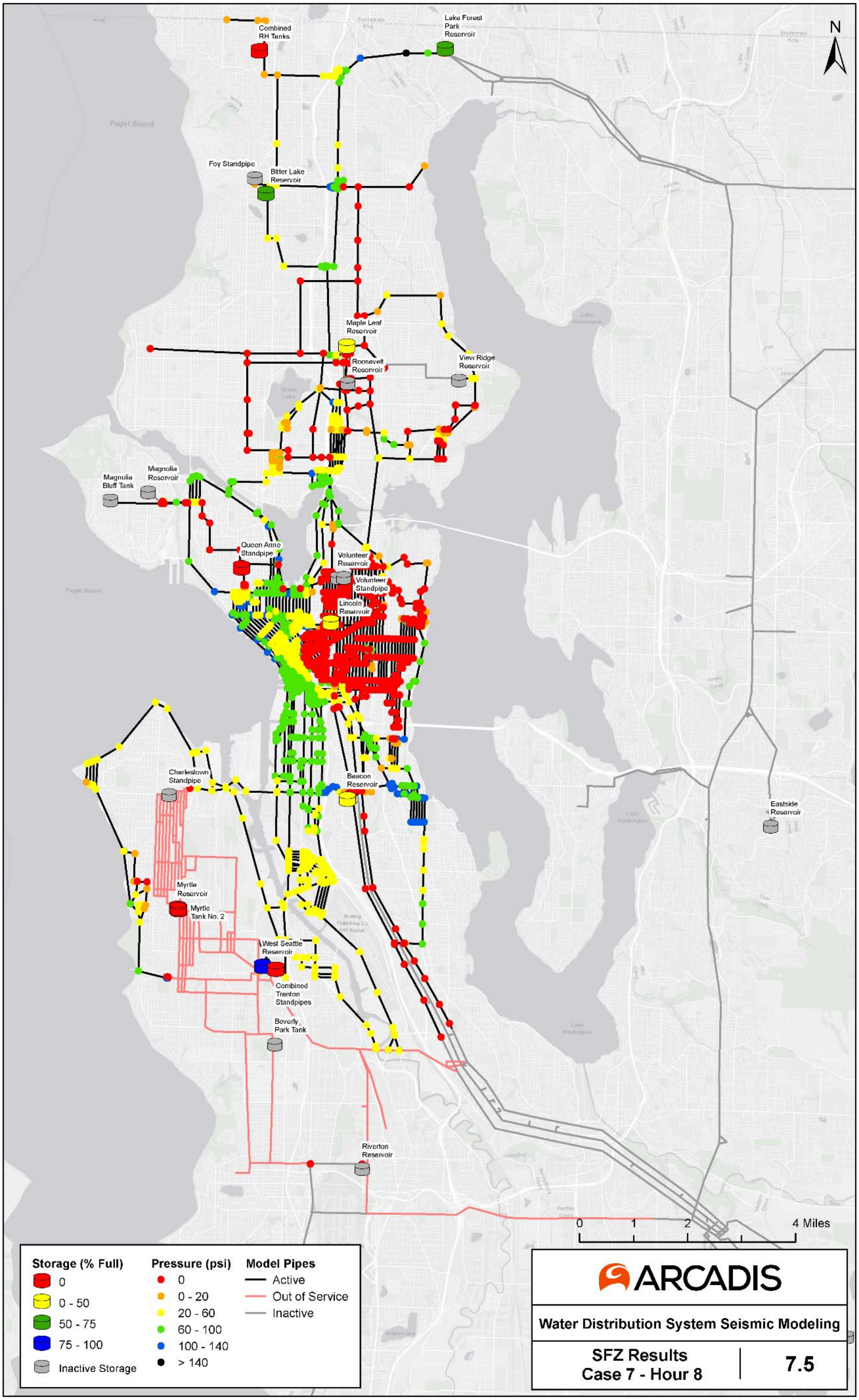
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 6
7.4

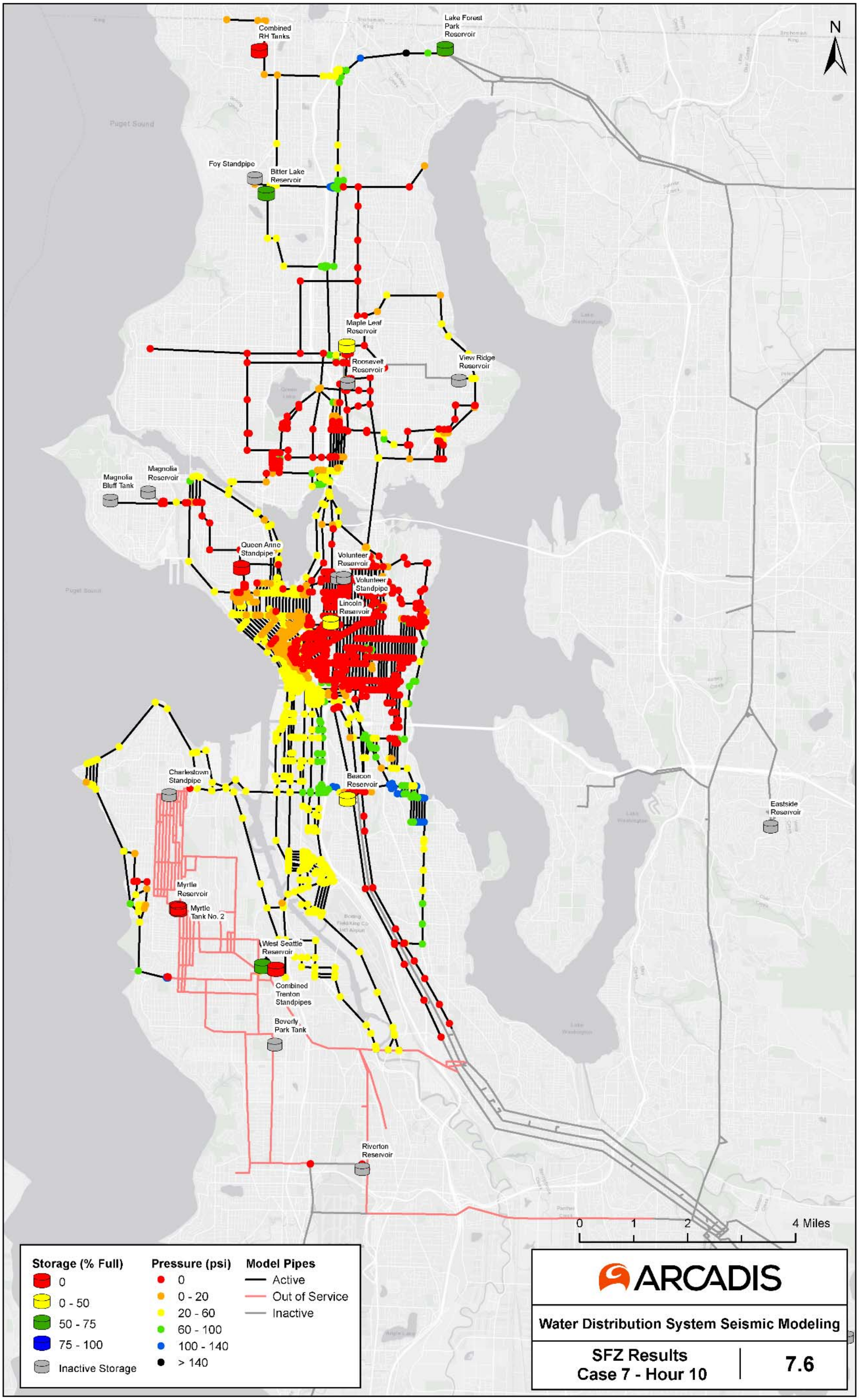


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 8

7.5


Combined RH Tanks
Lake Forest Park Reservoir
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Puget Sound
Foy Standpipe
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Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
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0
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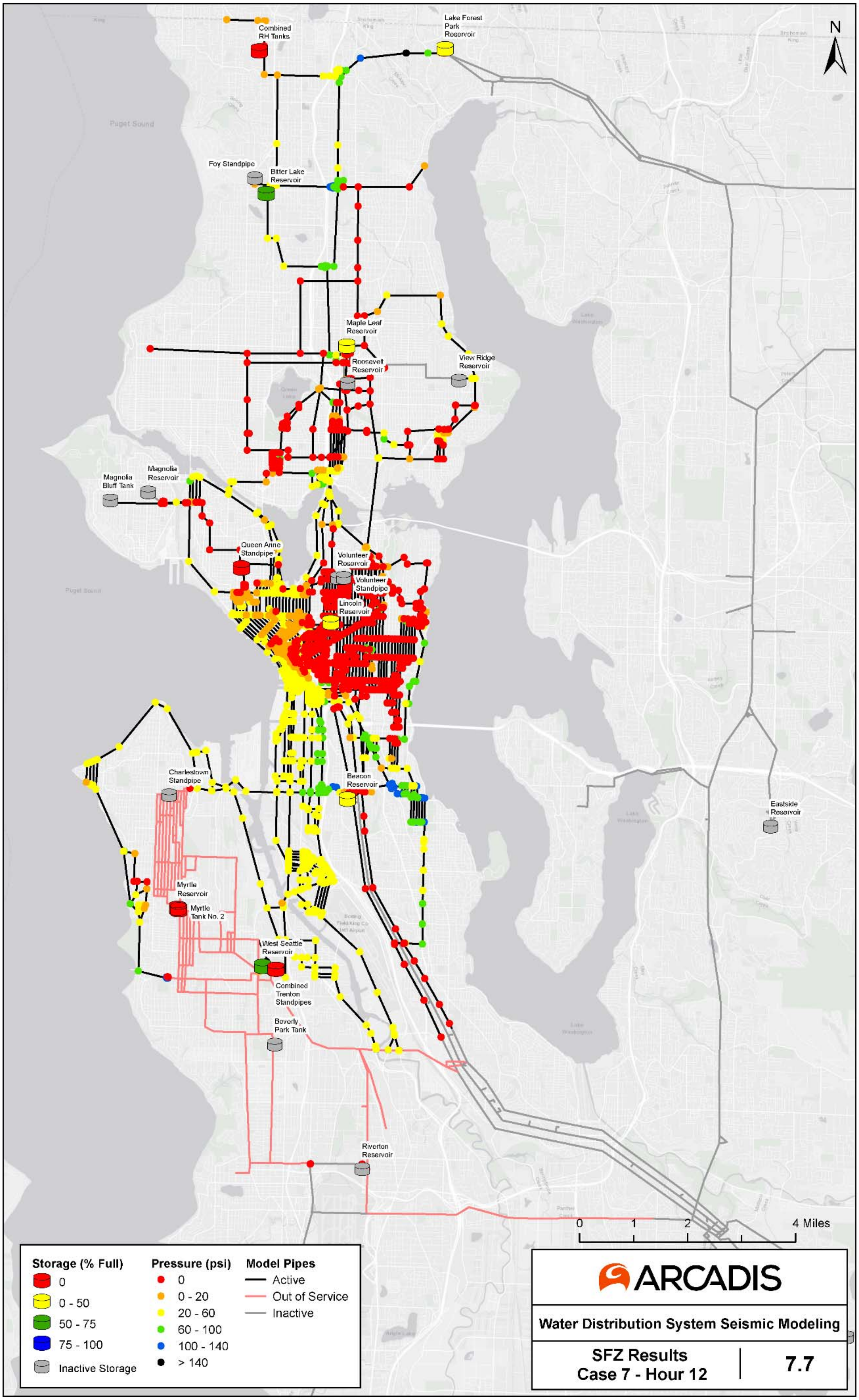
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 10
7.6



N
Combined RH Tanks
Lake Forest Park Reservoir
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
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75 - 100
Inactive Storage
Pressure (psi)
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20 - 60
60 - 100
100 - 140
> 140
Model Pipes
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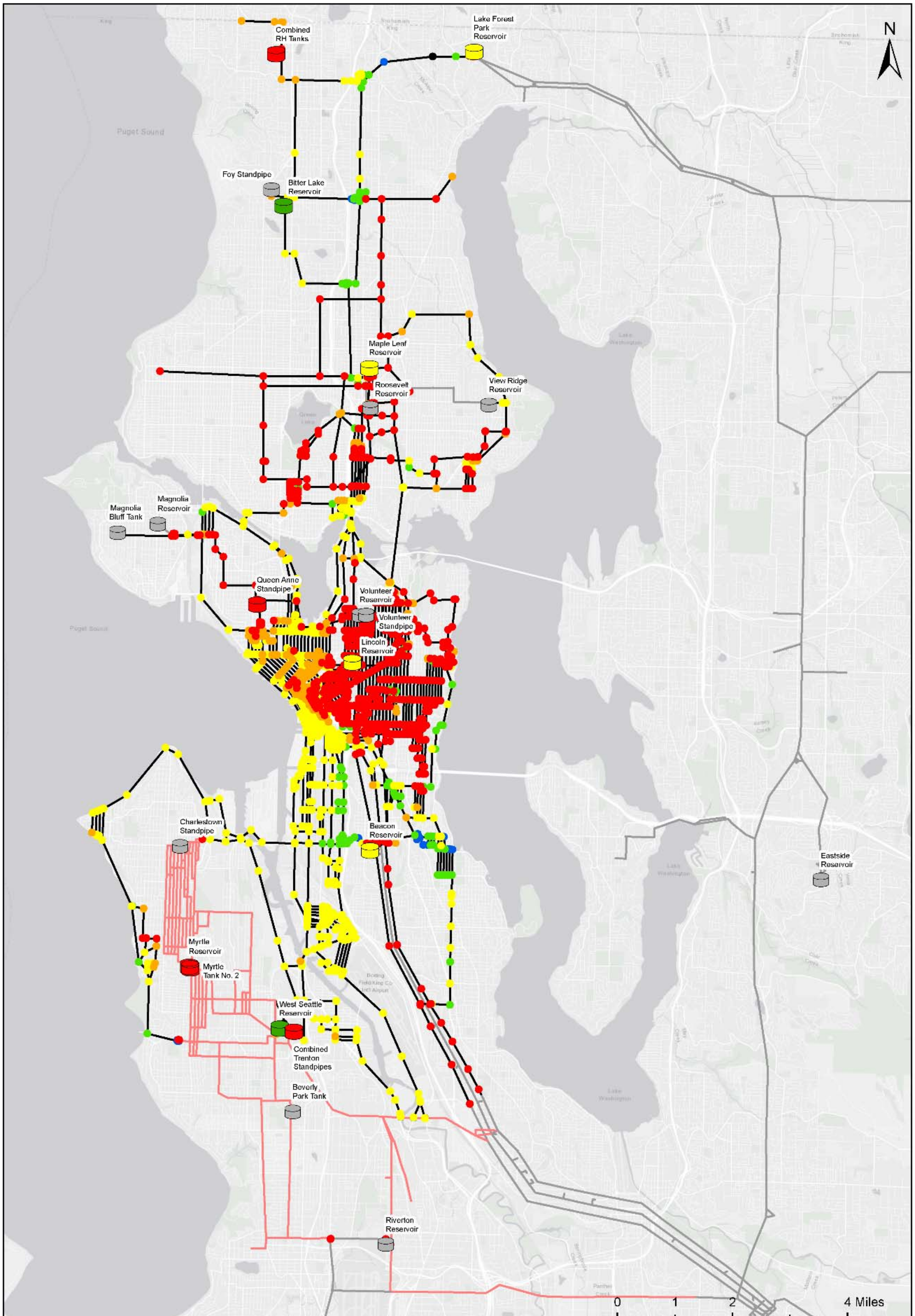
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 12
7.7

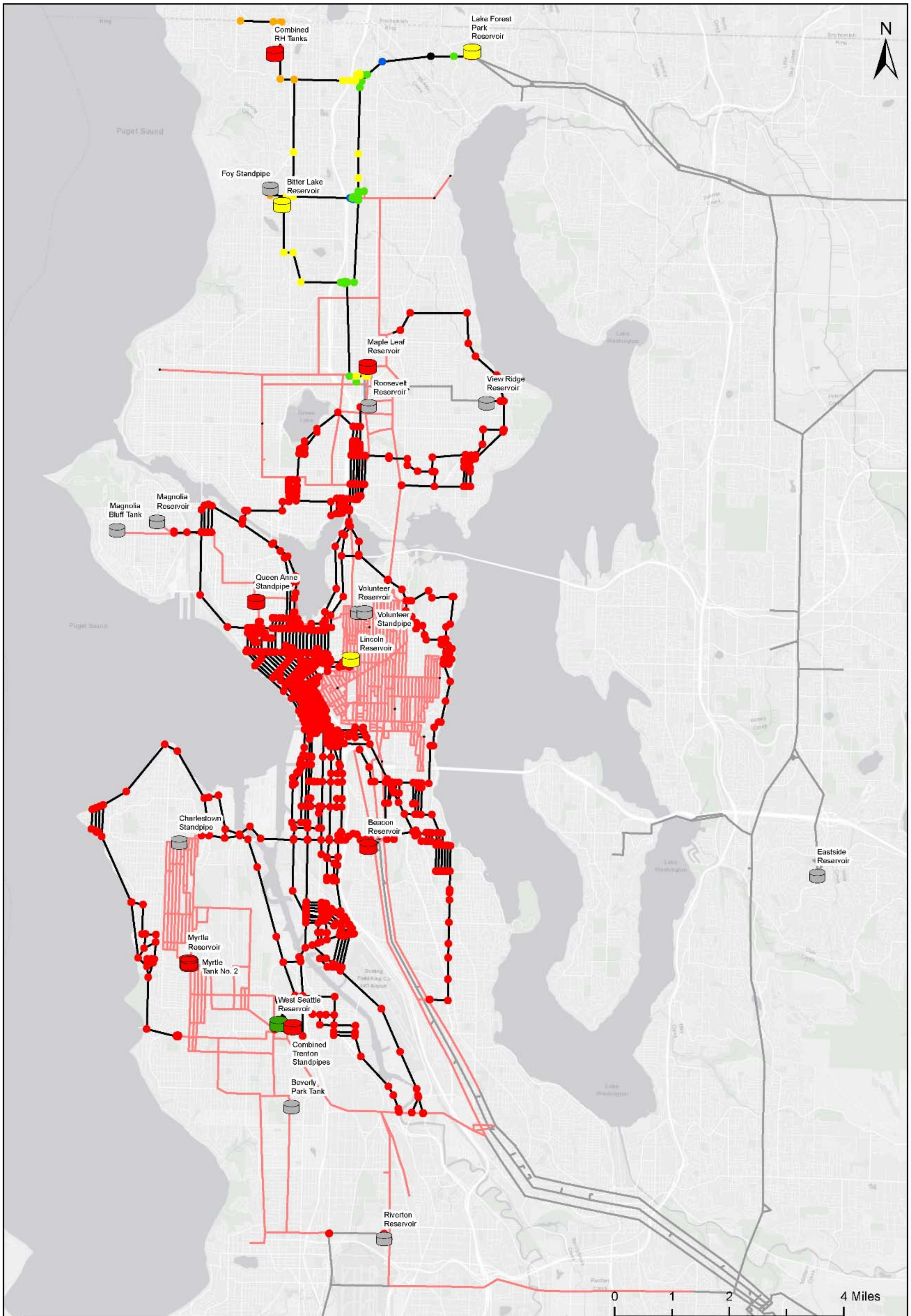


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 14

7.8

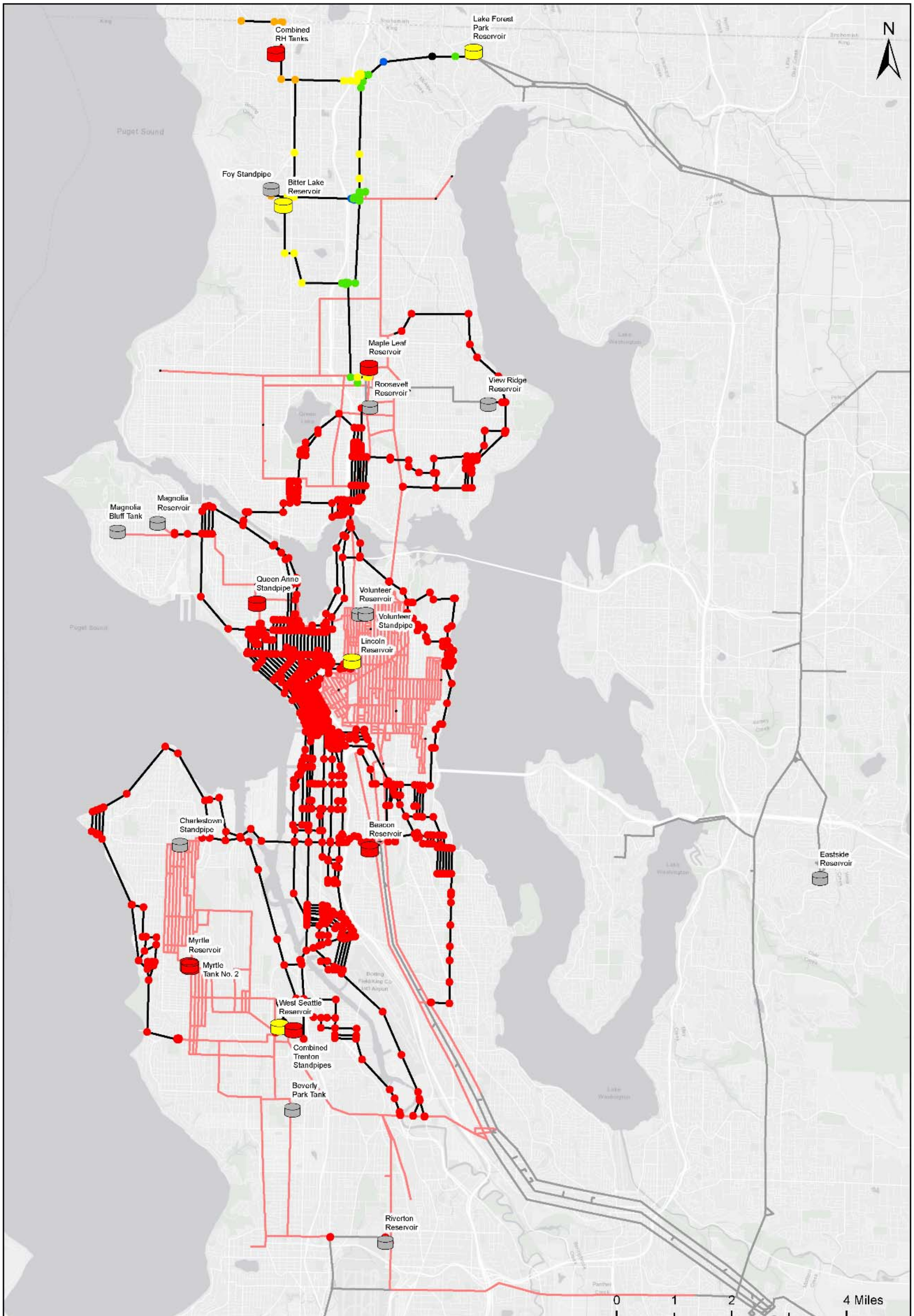


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 16

7.9

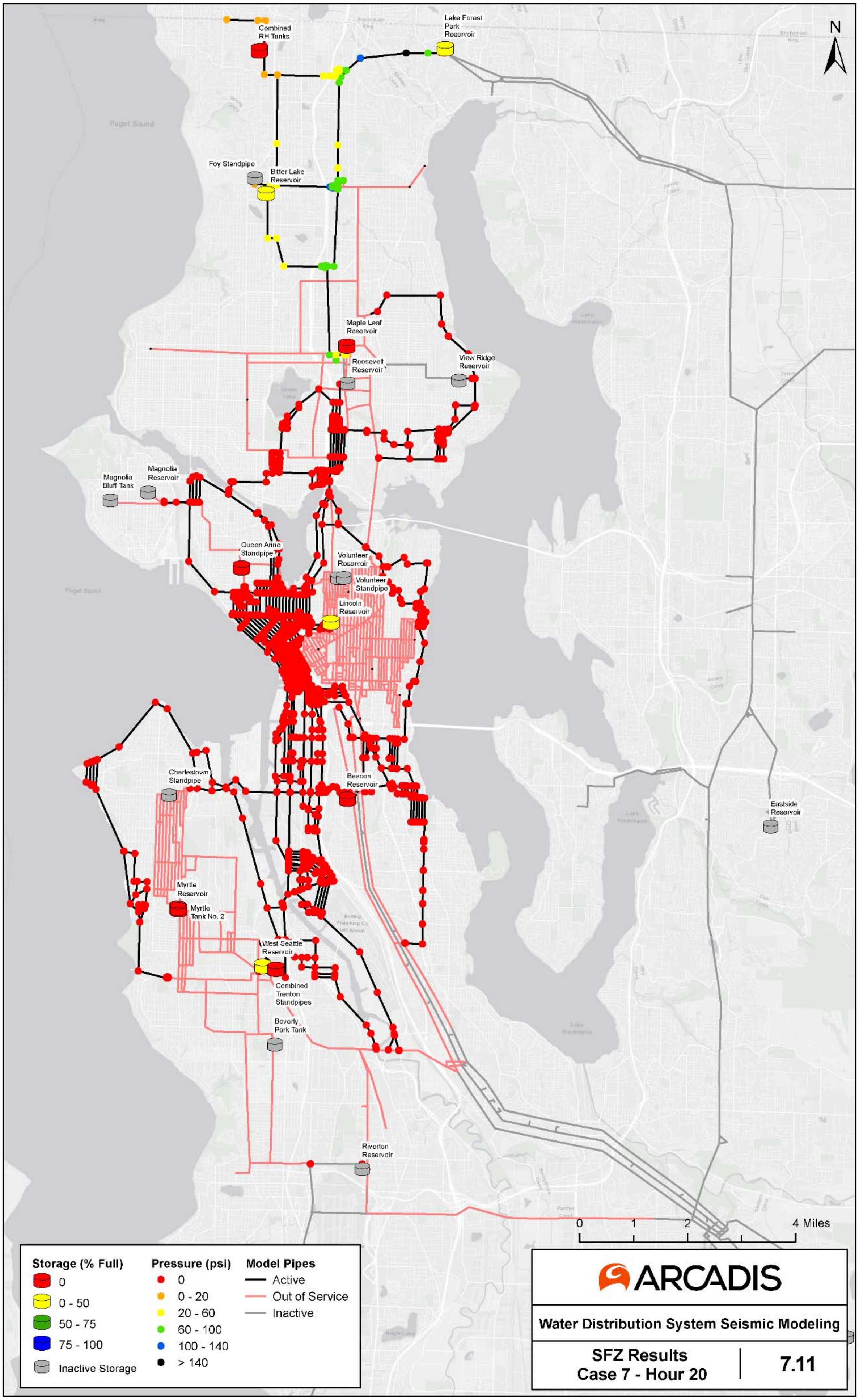


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 18

7.10


Combined
RH Tanks
Lake Forest
Park
Reservoir
N
Puget Sound
Foy Standpipe
Bitter Lake
Reservoir
Maple Leaf
Reservoir
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Reservoir
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Reservoir
Magnolia
Bluff Tank
Magnolia
Reservoir
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Standpipe
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Reservoir
Volunteer
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Lincoln
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Standpipe
Beacon
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Eastside
Reservoir
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Myrtle
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Trenton
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Boverly
Park Tank
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Reservoir
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100 - 140
> 140
Model Pipes
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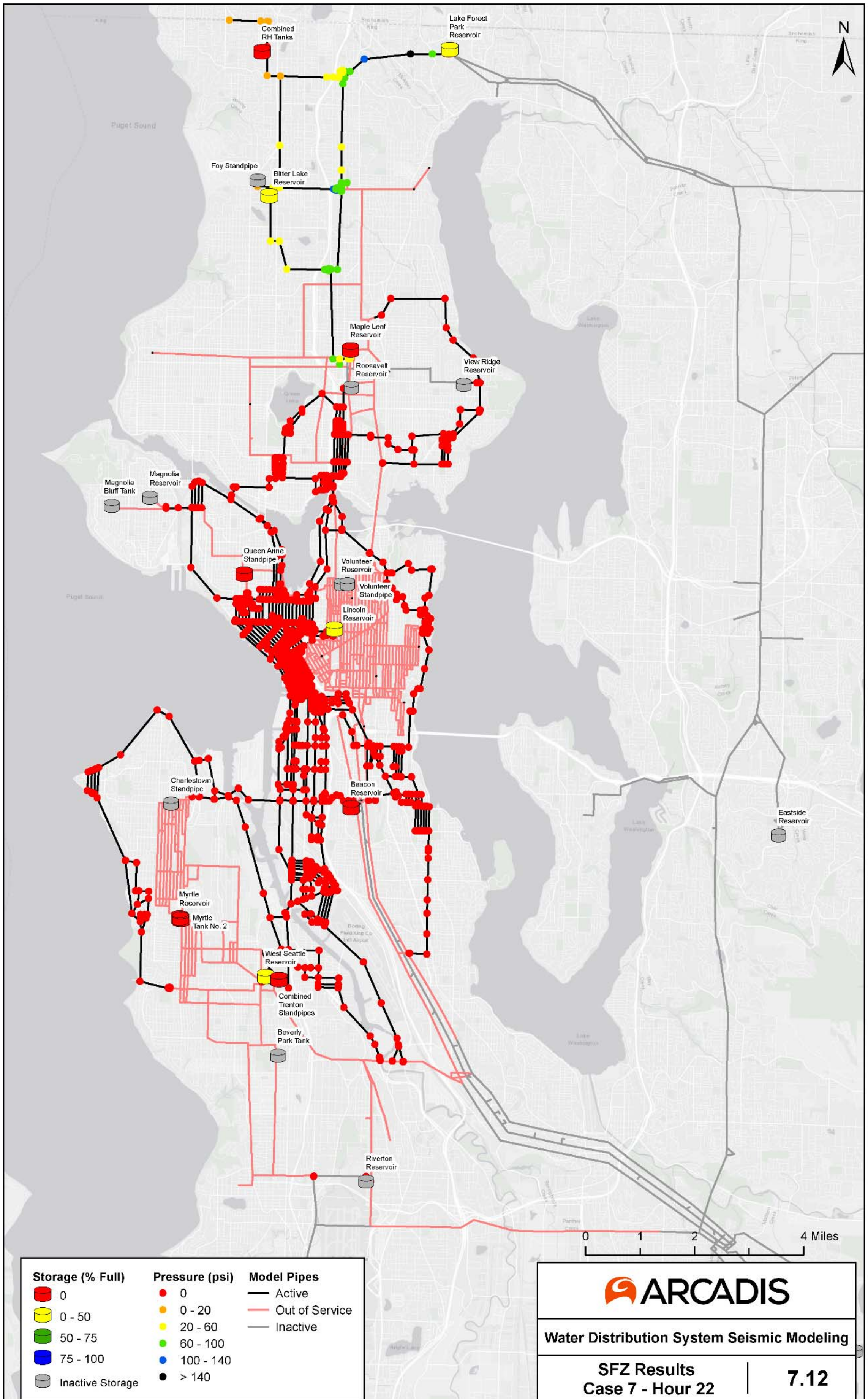
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 20
7.11

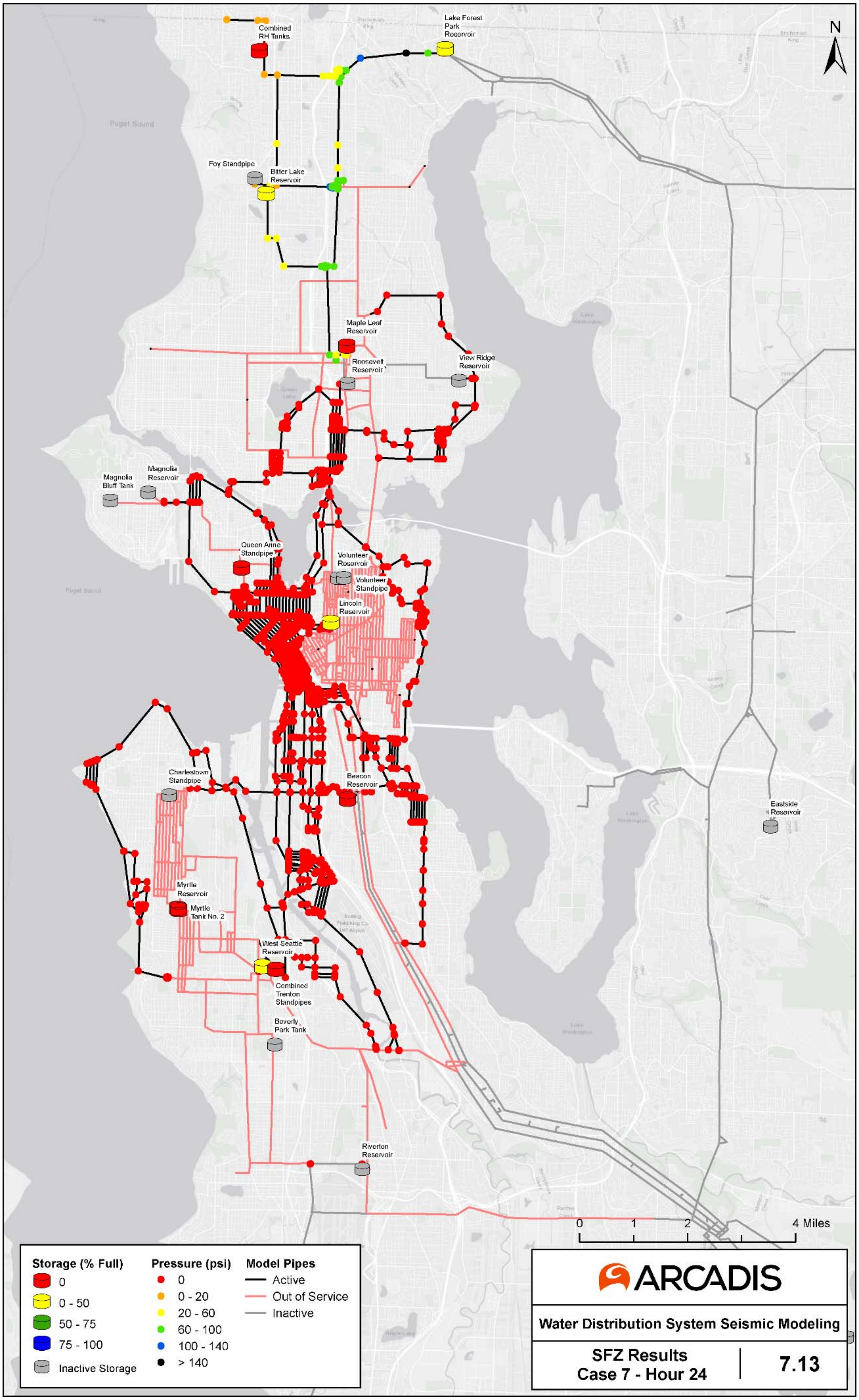


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 22

7.12



ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 24

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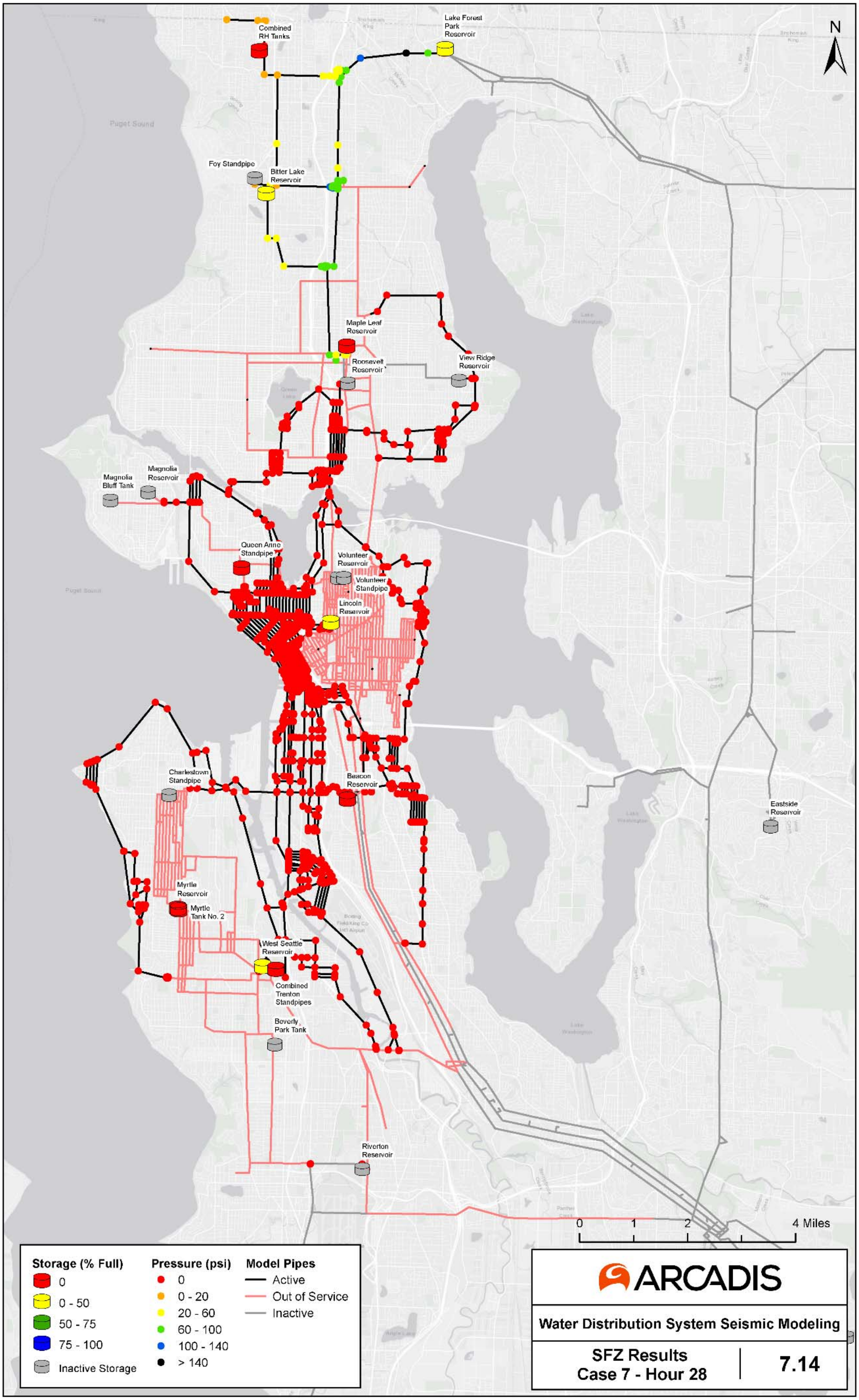
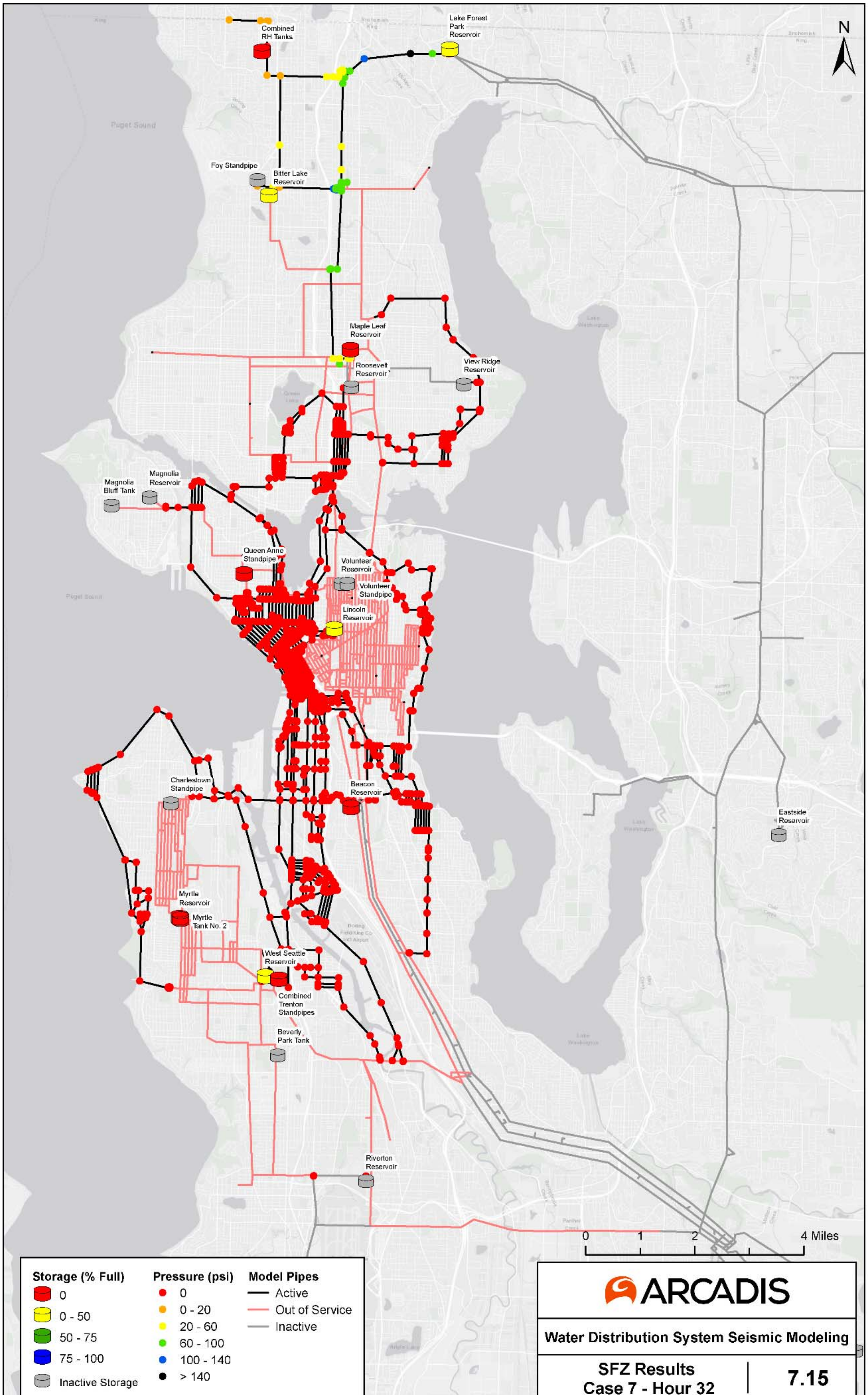


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 28

7.14



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Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 32

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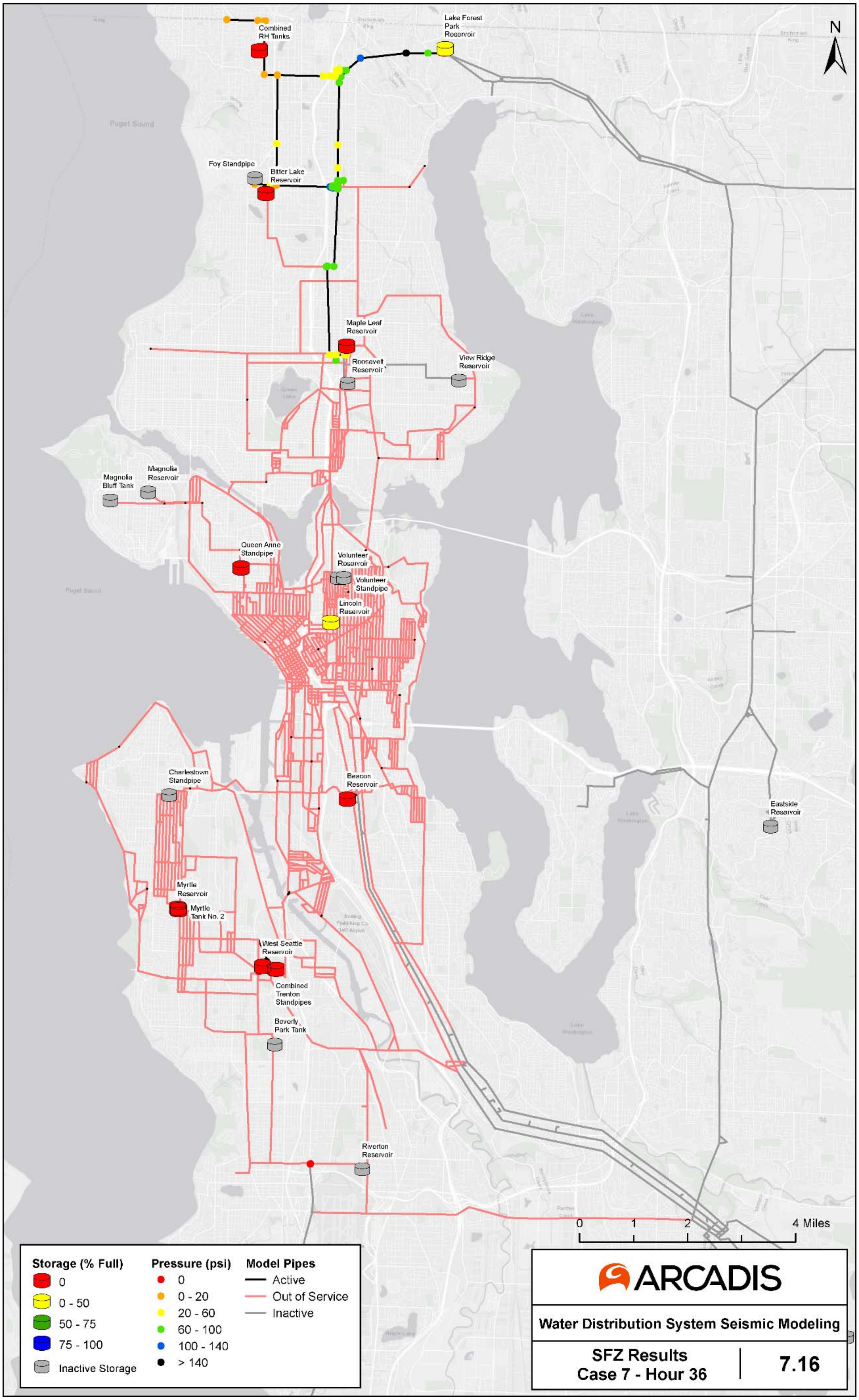

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 36

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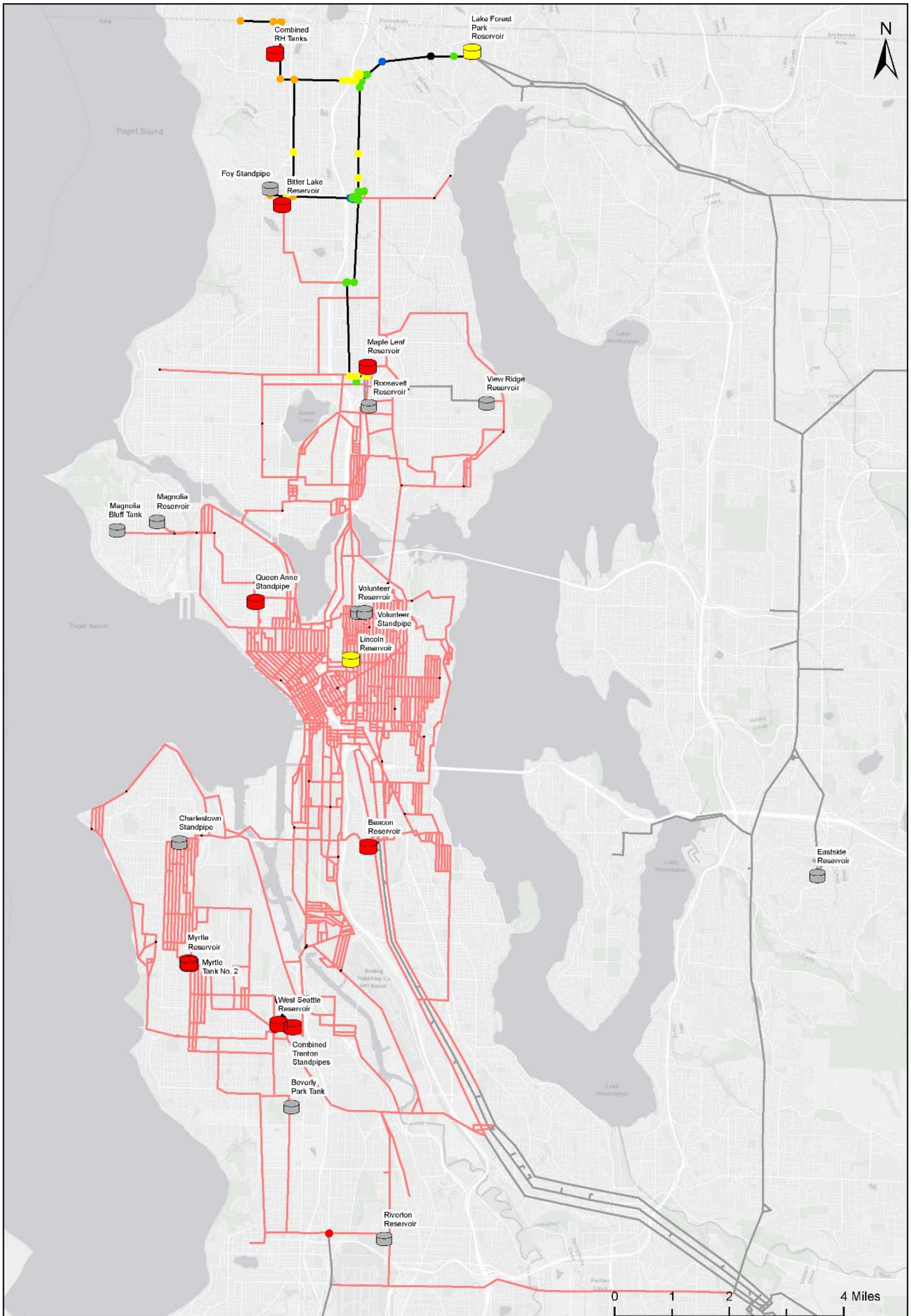
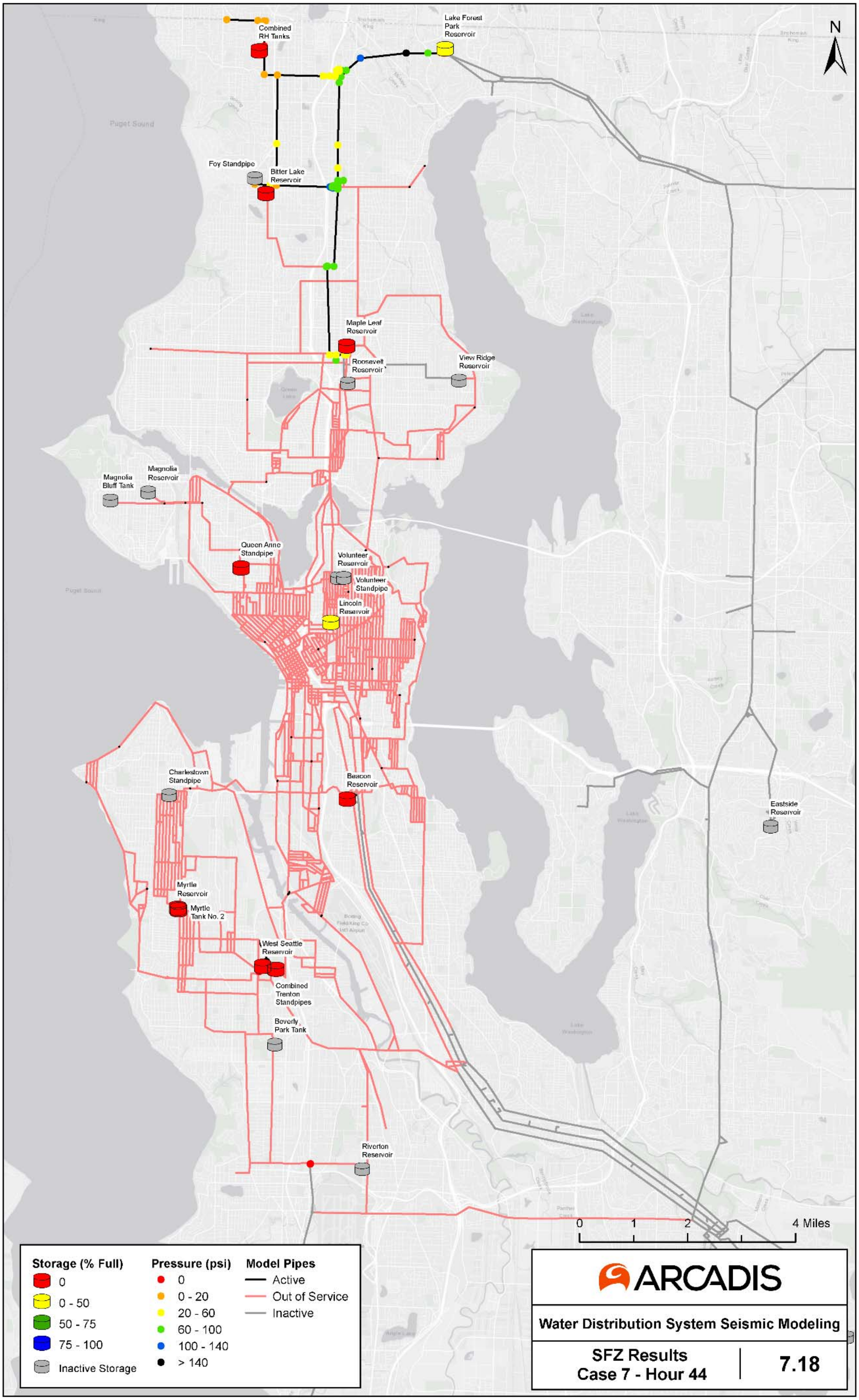


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 40

7.17


N
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Puget Sound
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100 - 140
> 140
Model Pipes
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Out of Service
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ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 7 - Hour 44
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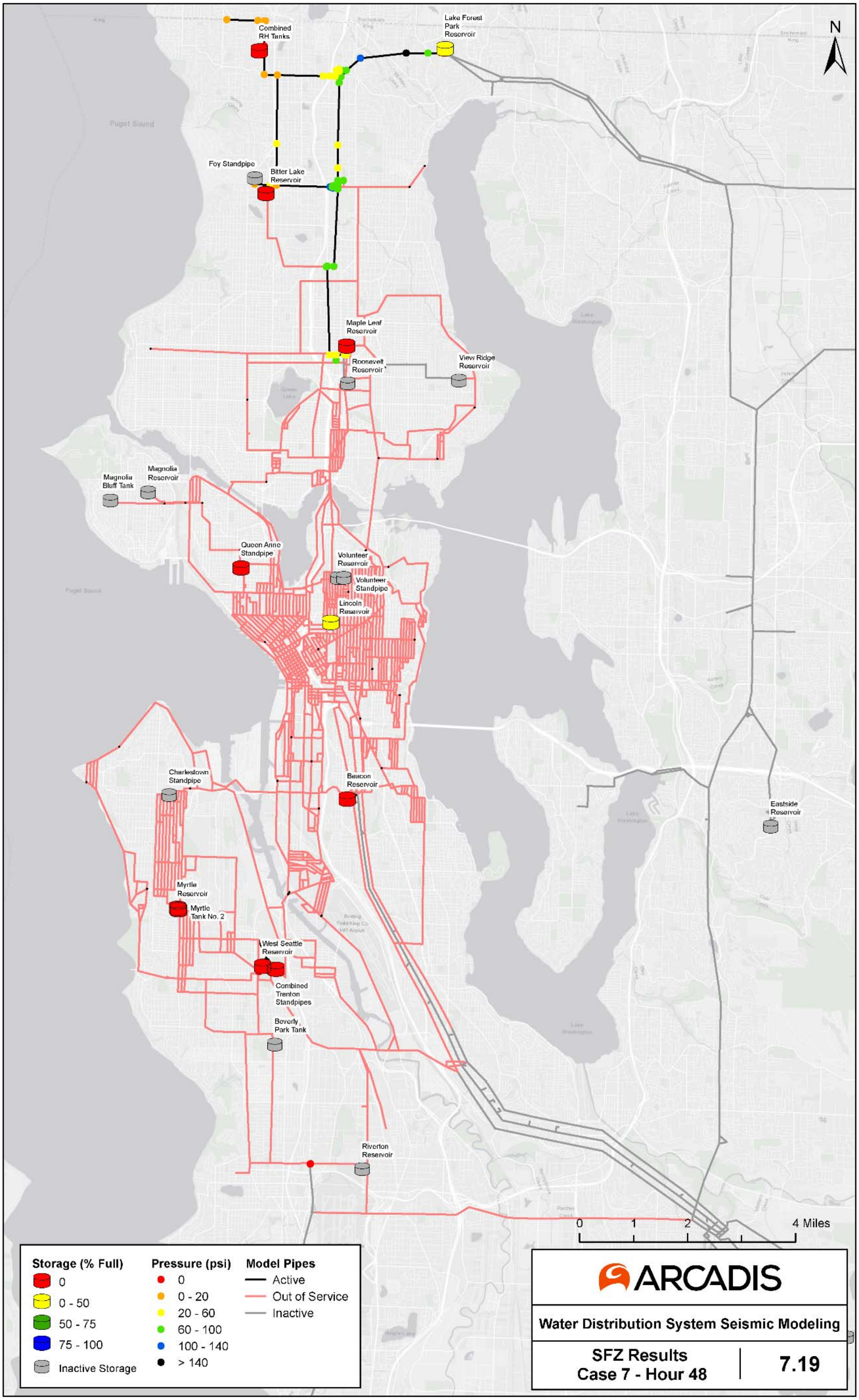


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 7 - Hour 48

7.19

M7.0 Seattle Fault Zone Case 8 (No Improvements But Roosevelt and Volunteer Park Reservoirs Online) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/6/2018

Seattle Fault Seismic Event

Case 8 Same as "Base" case

Roosevelt and Volunteer Park Reservoir are Functional

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	271,913	249,543	22,370	78%	285.5
3	252,683	233,750	18,933	68%	236.2
12	186,861	171,987	14,874	50%	117.5
22	41,910	35,431	6,480	22%	32.3
32	10,741	10,741	-	3%	4.0
48	-	-	-	2%	0.5

Model Regions Forced Out of Service During Simulation

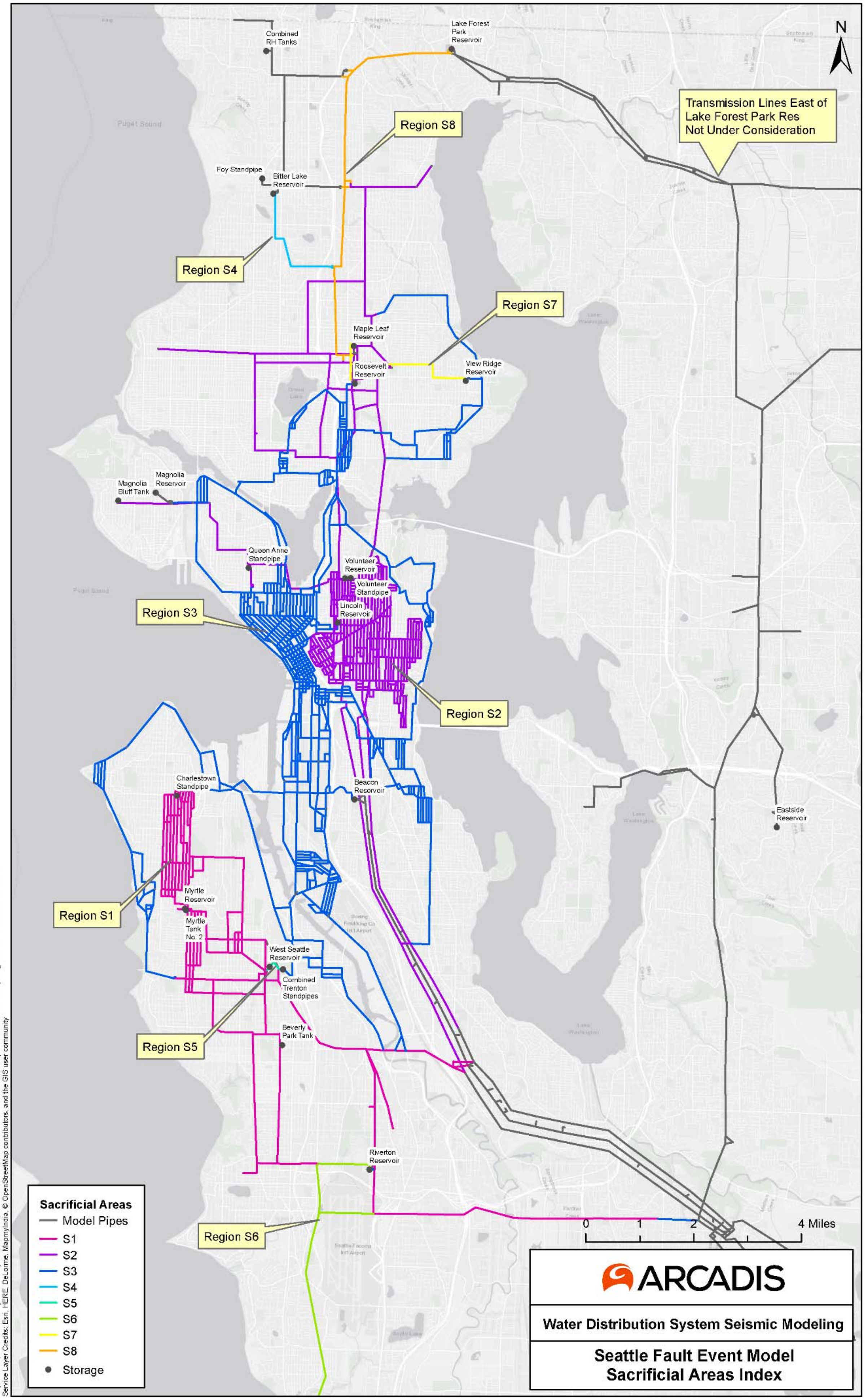
Time	Region
3	S1
20	S2
32	S4
35	S3

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 8.1	Hr 0	Fig. 8.5	Hr 8	Fig. 8.9	Hr 16	Fig. 8.13	Hr 24	Fig. 8.17	Hr 40
Fig. 8.2	Hr 2	Fig. 8.6	Hr 10	Fig. 8.10	Hr 18	Fig. 8.14	Hr 28	Fig. 8.18	Hr 44
Fig. 8.3	Hr 4	Fig. 8.7	Hr 12	Fig. 8.11	Hr 20	Fig. 8.15	Hr 32	Fig. 8.19	Hr 48
Fig. 8.4	Hr 6	Fig. 8.8	Hr 14	Fig. 8.12	Hr 22	Fig. 8.16	Hr 36		



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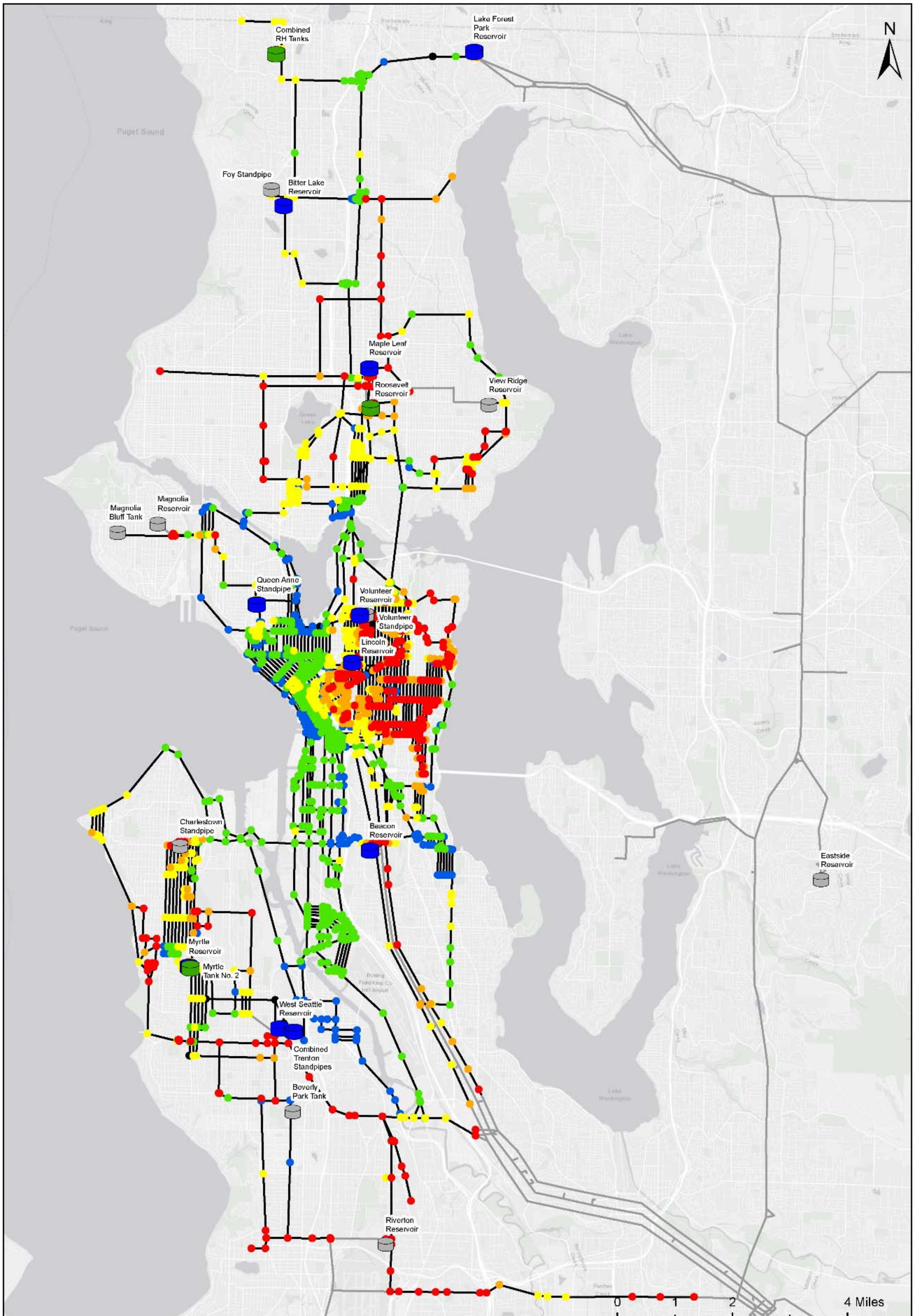
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



Storage (% Full)
- 0
- 0 - 50
- 50 - 75
- 75 - 100
- Inactive Storage

Pressure (psi)
- 0
- 0 - 20
- 20 - 60
- 60 - 100
- 100 - 140
- > 140

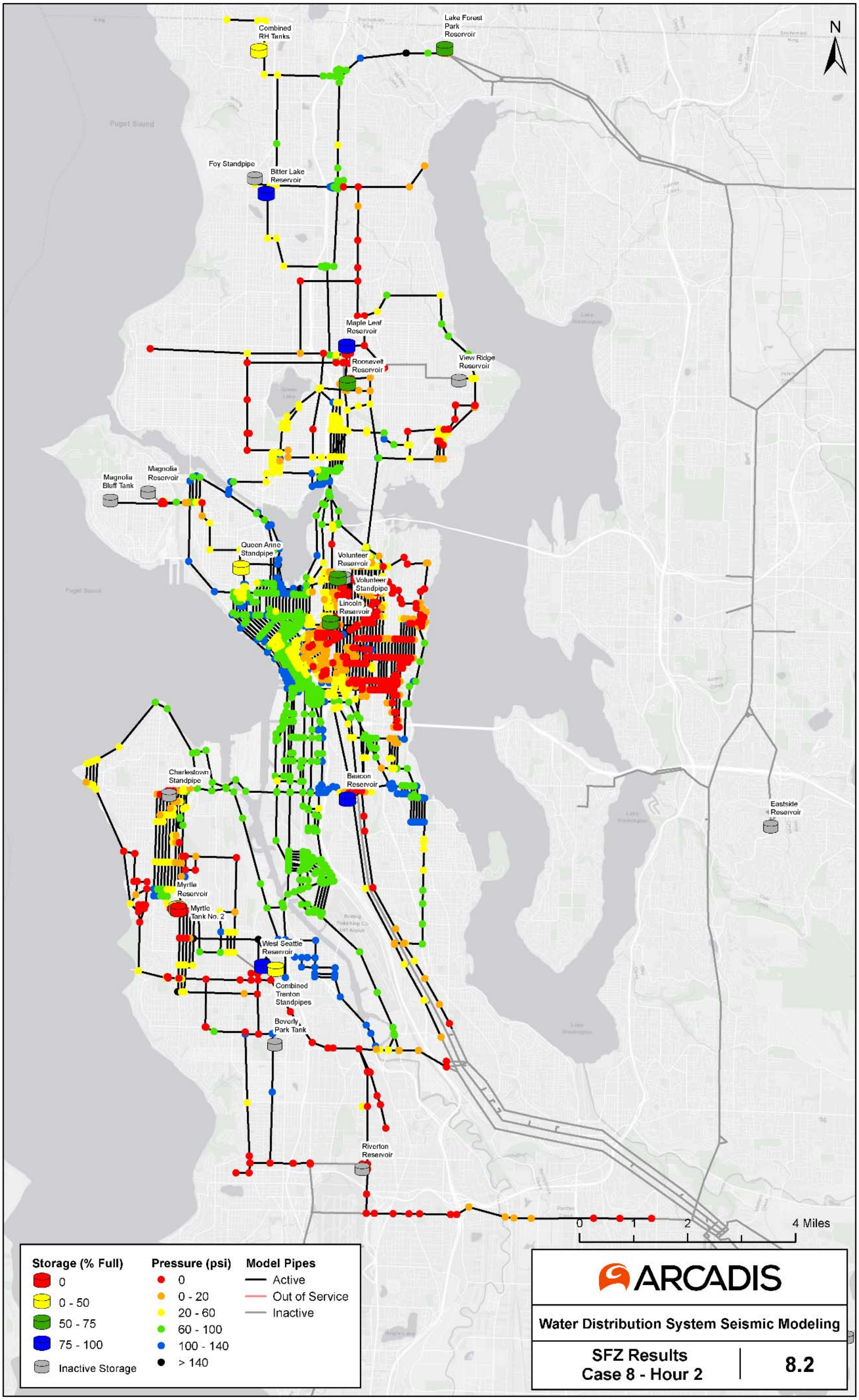
Model Pipes
- Active
- Out of Service
- Inactive

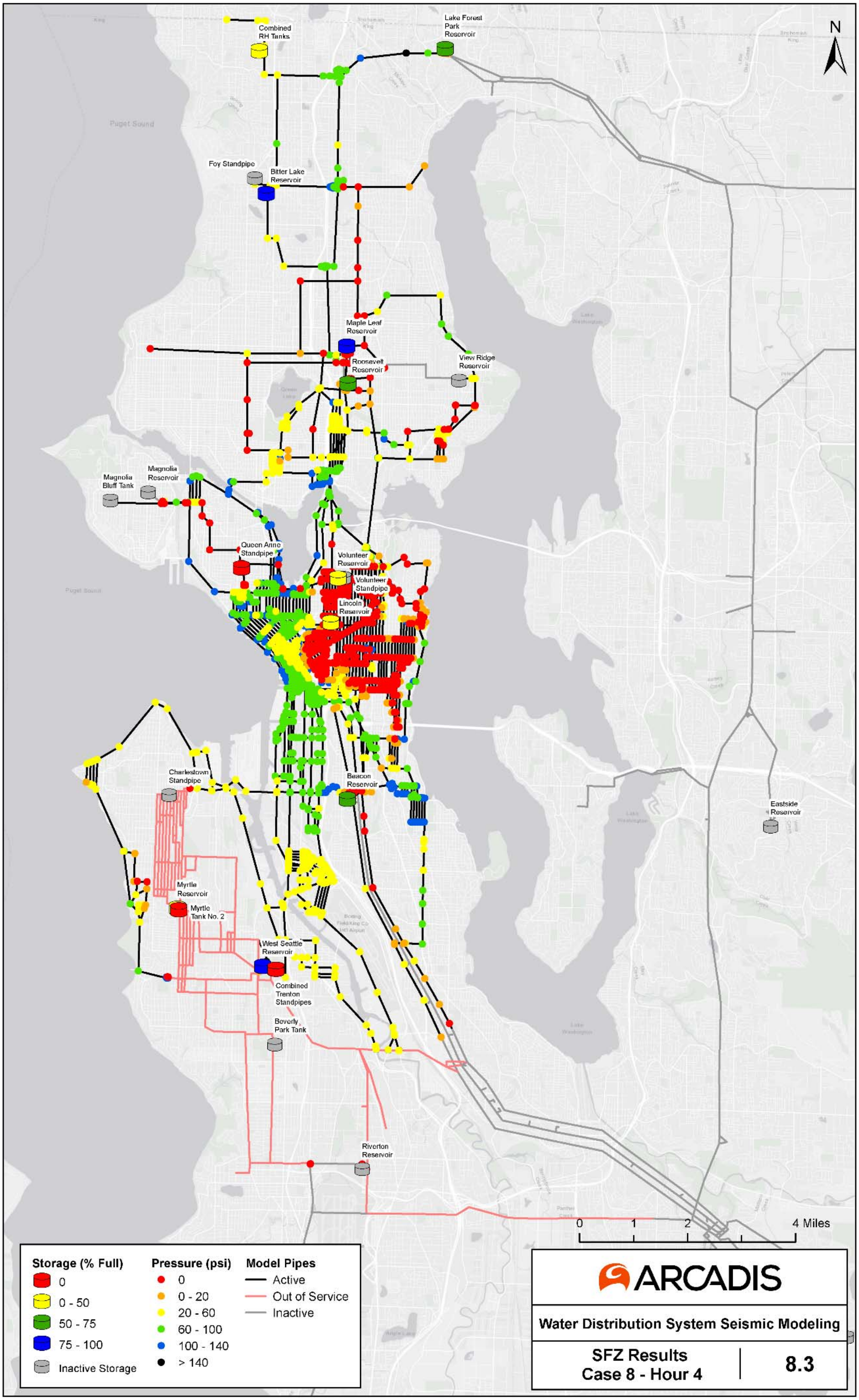
ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 0

8.1


N
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
Puget Sound
0
1
2
4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 2
8.2

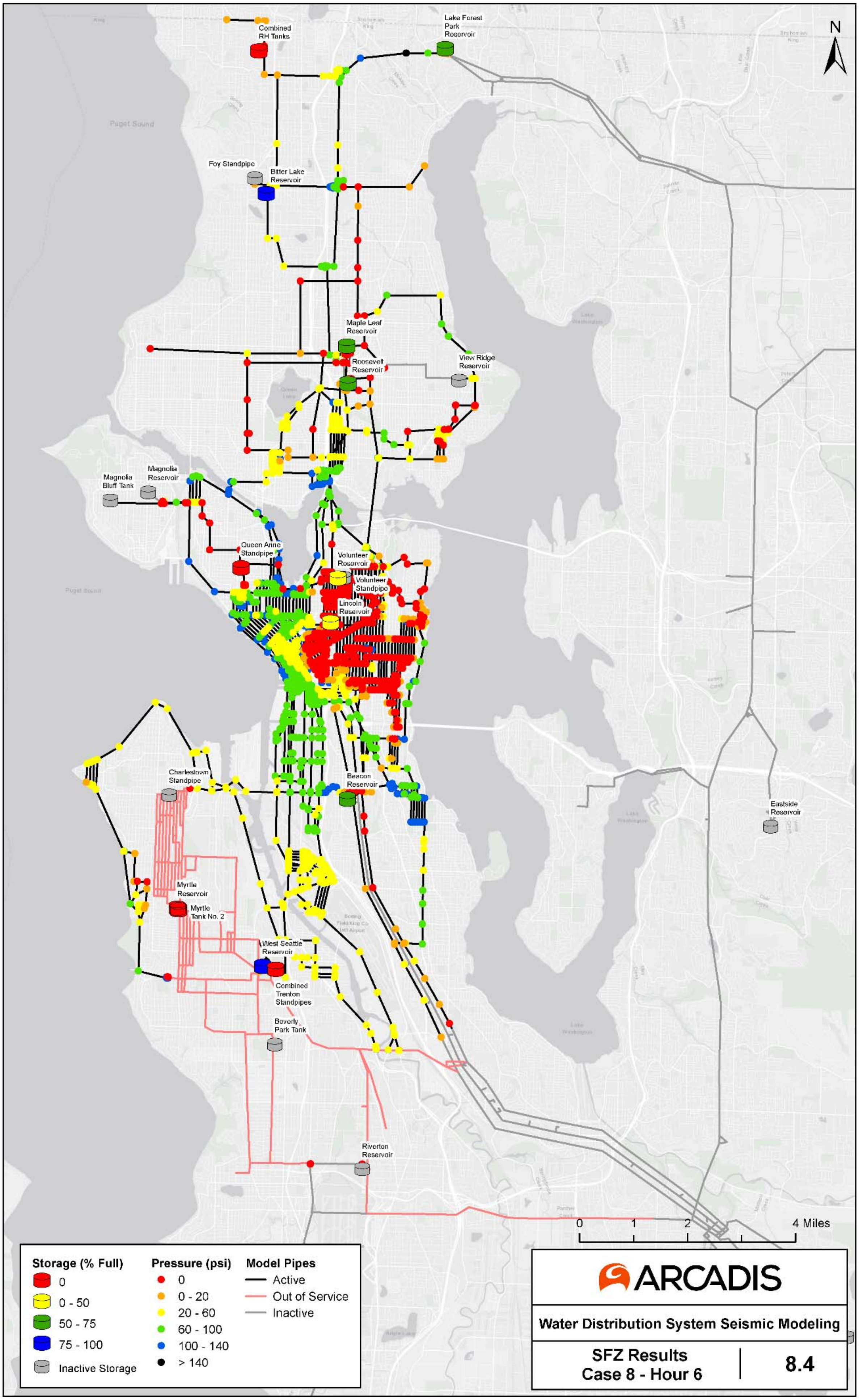


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 4

8.3



N
Combined RH Tanks
Lake Forest Park Reservoir
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
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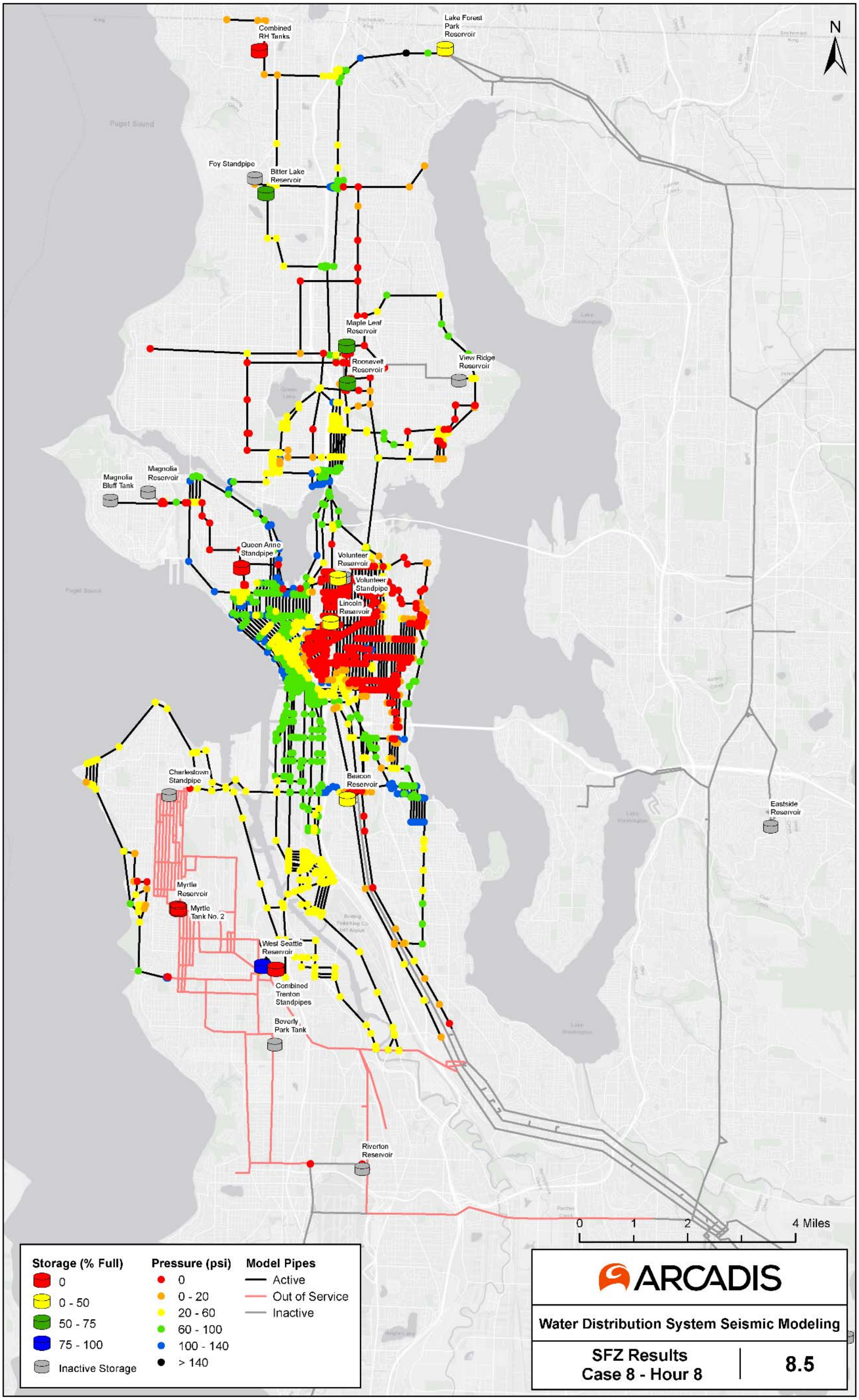
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 6
8.4


Combined RH Tanks
Lake Forest Park Reservoir
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Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
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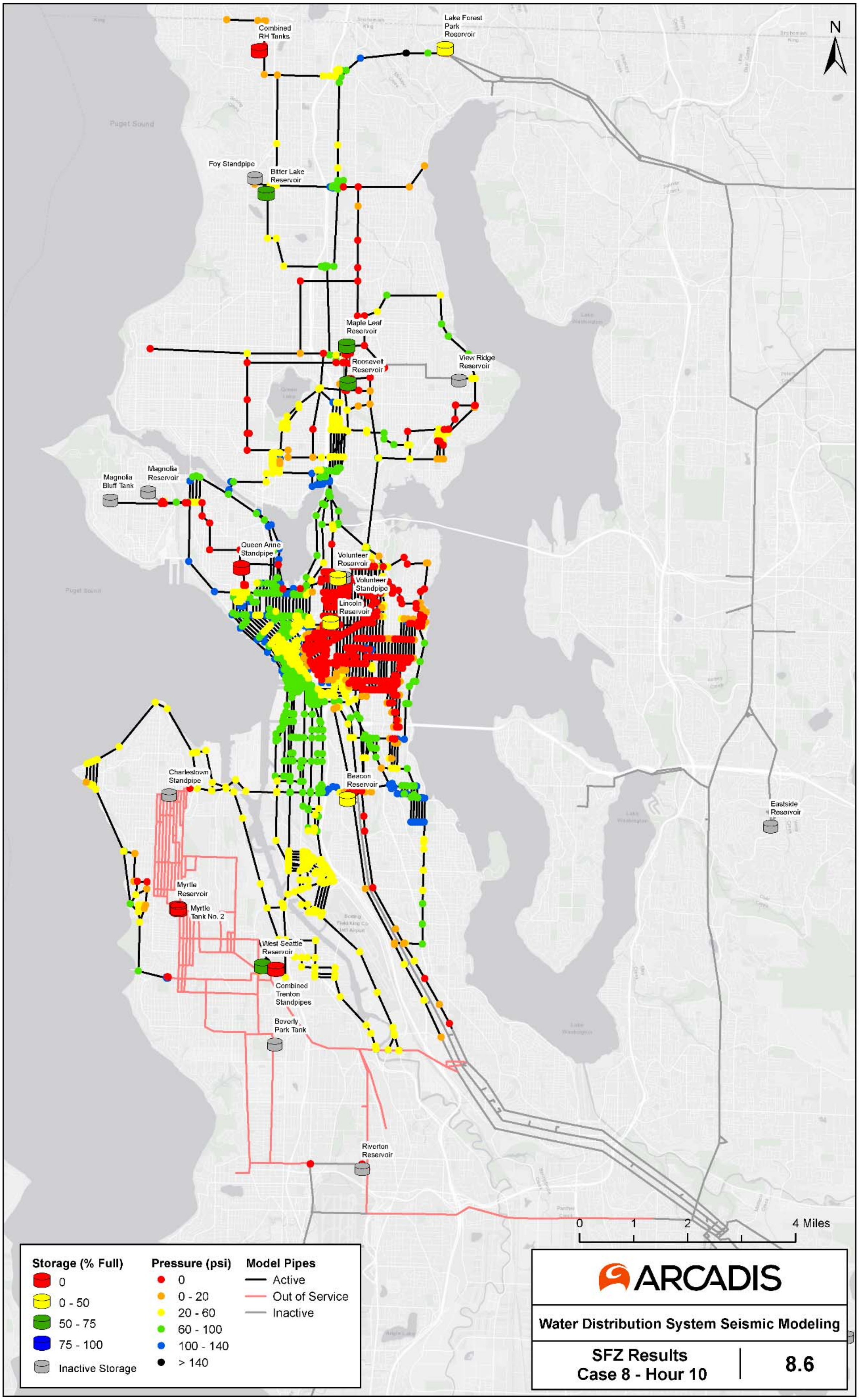
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 8
8.5


N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
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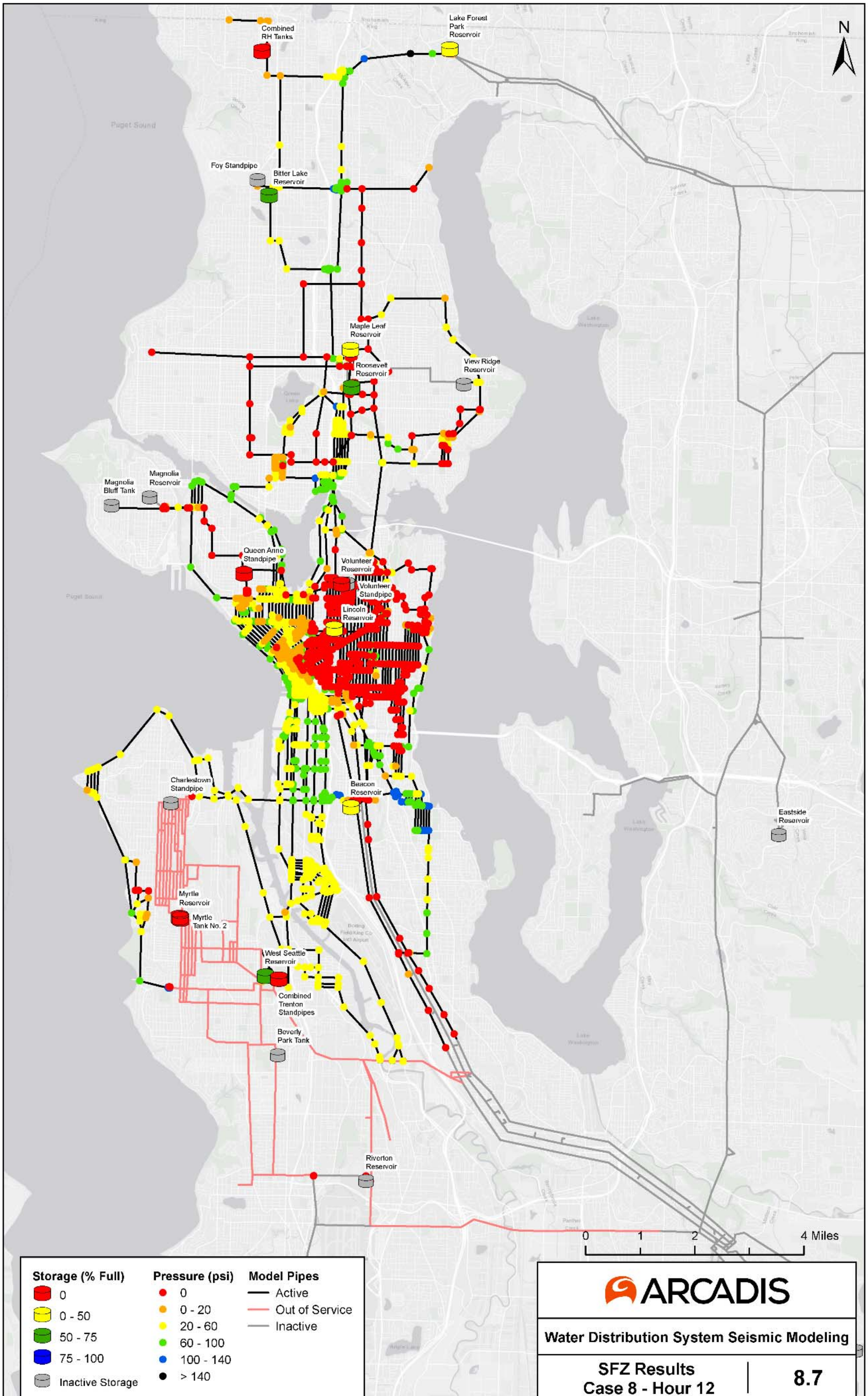
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Boverly Park Tank
Riverton Reservoir
Puget Sound
0
1
2
4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 10
8.6

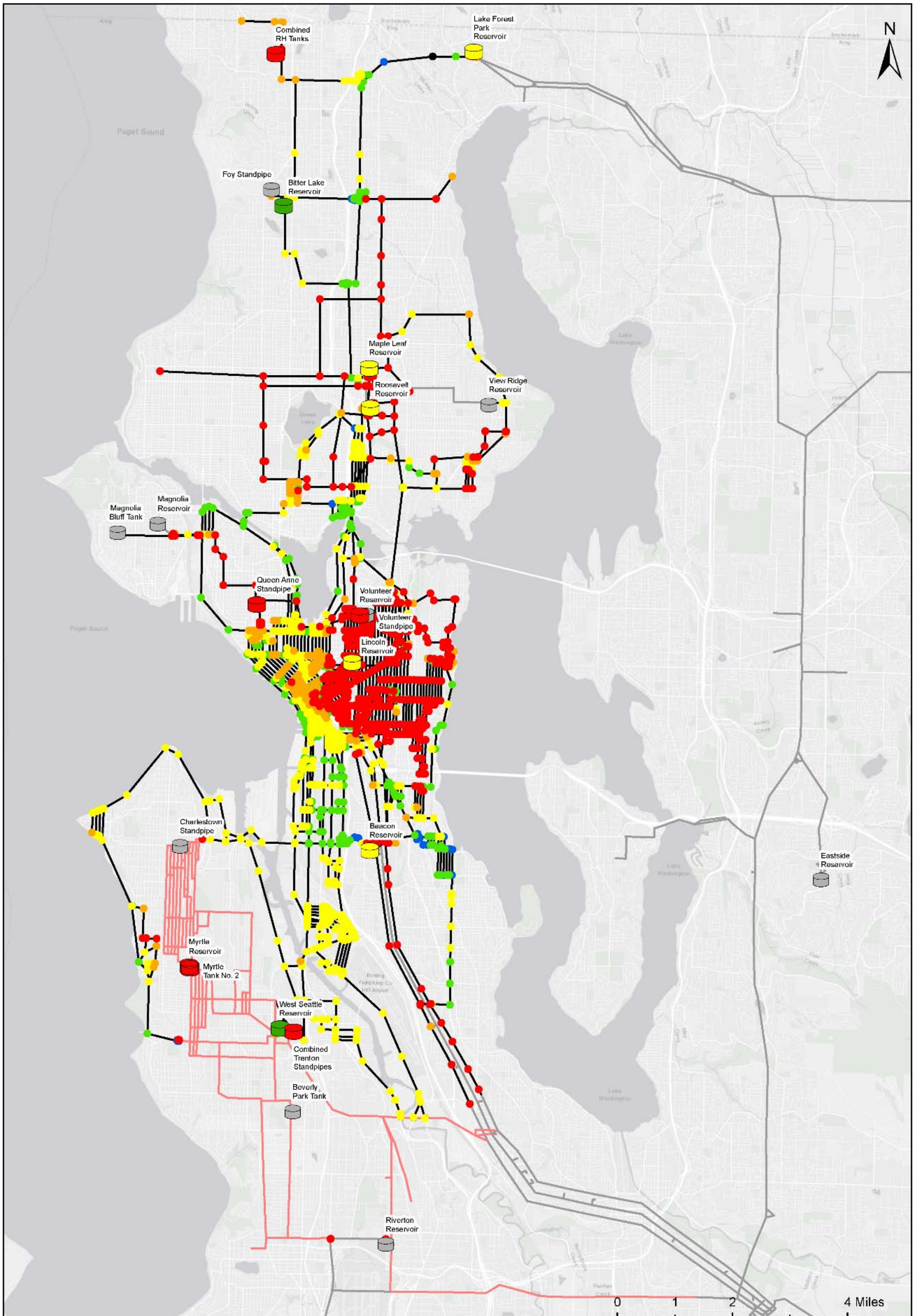


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 12

8.7



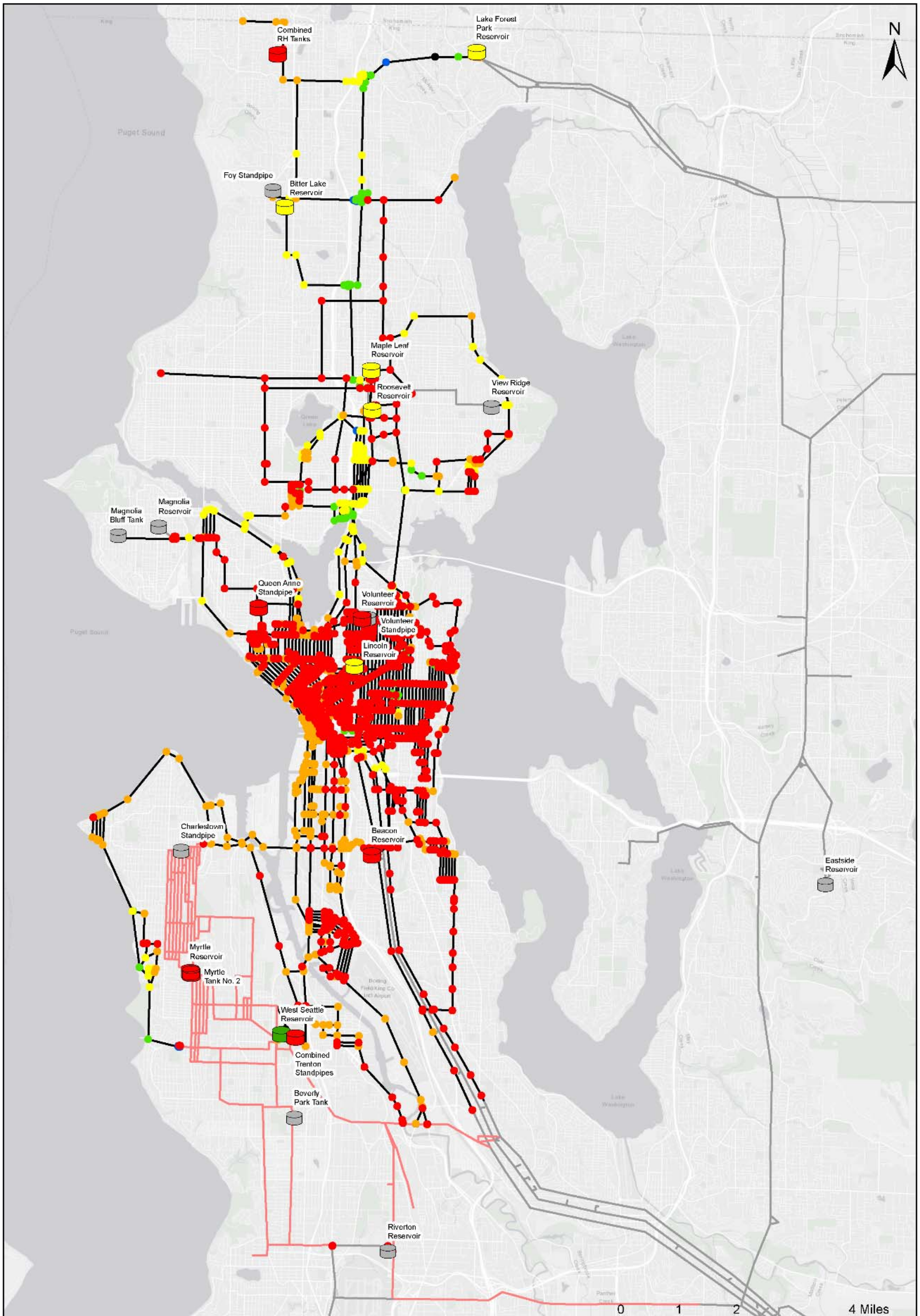
Storage (% Full)	Pressure (psi)	Model Pipes
0	0	Active
0 - 50	0 - 20	Out of Service
50 - 75	20 - 60	Inactive
75 - 100	60 - 100	
Inactive Storage	100 - 140	
	> 140	

ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 14

8.8

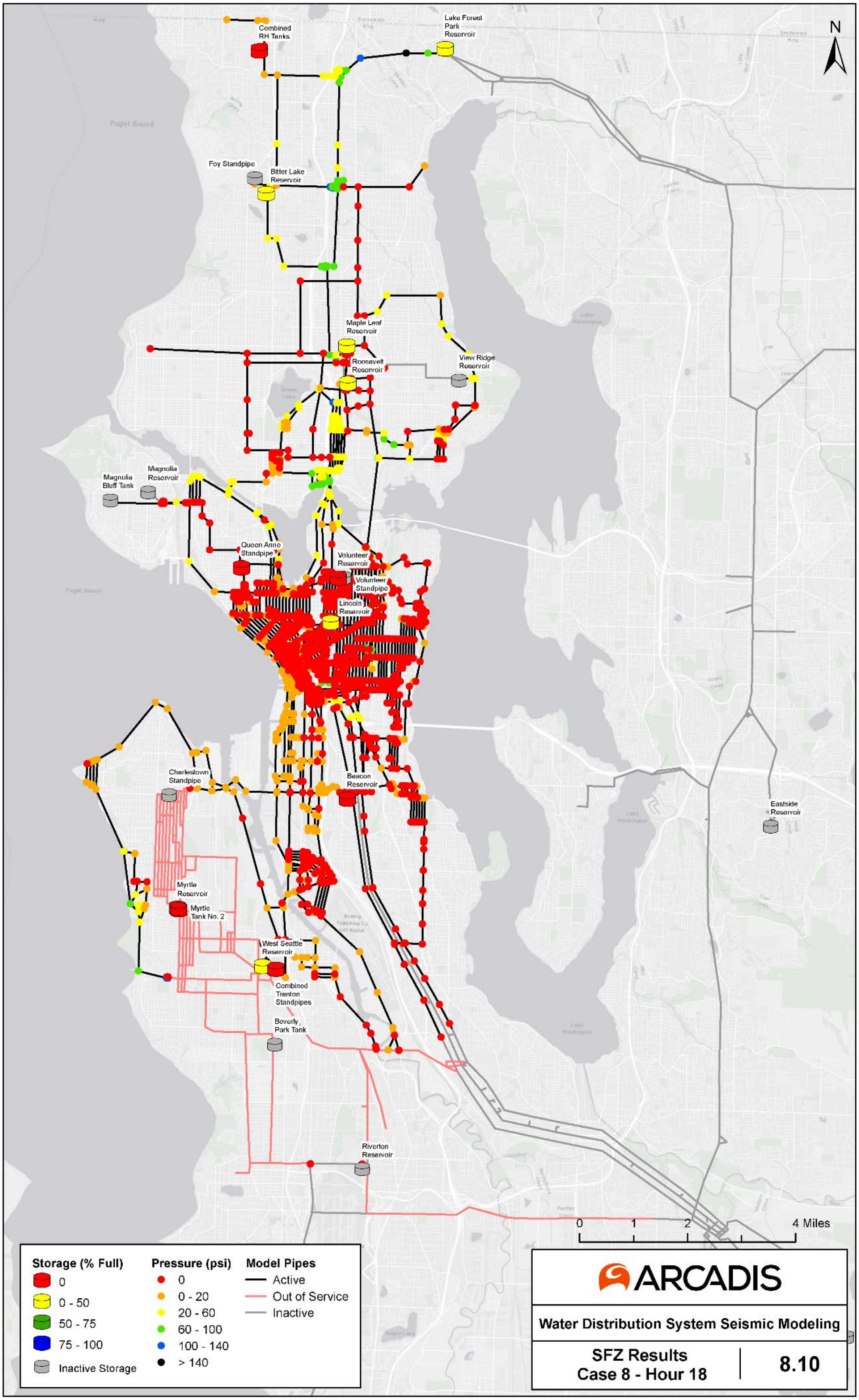


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 16

8.9



Combined RH Tanks
Lake Forest Park Reservoir
N
Puget Sound
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Myrtle Tank No. 2
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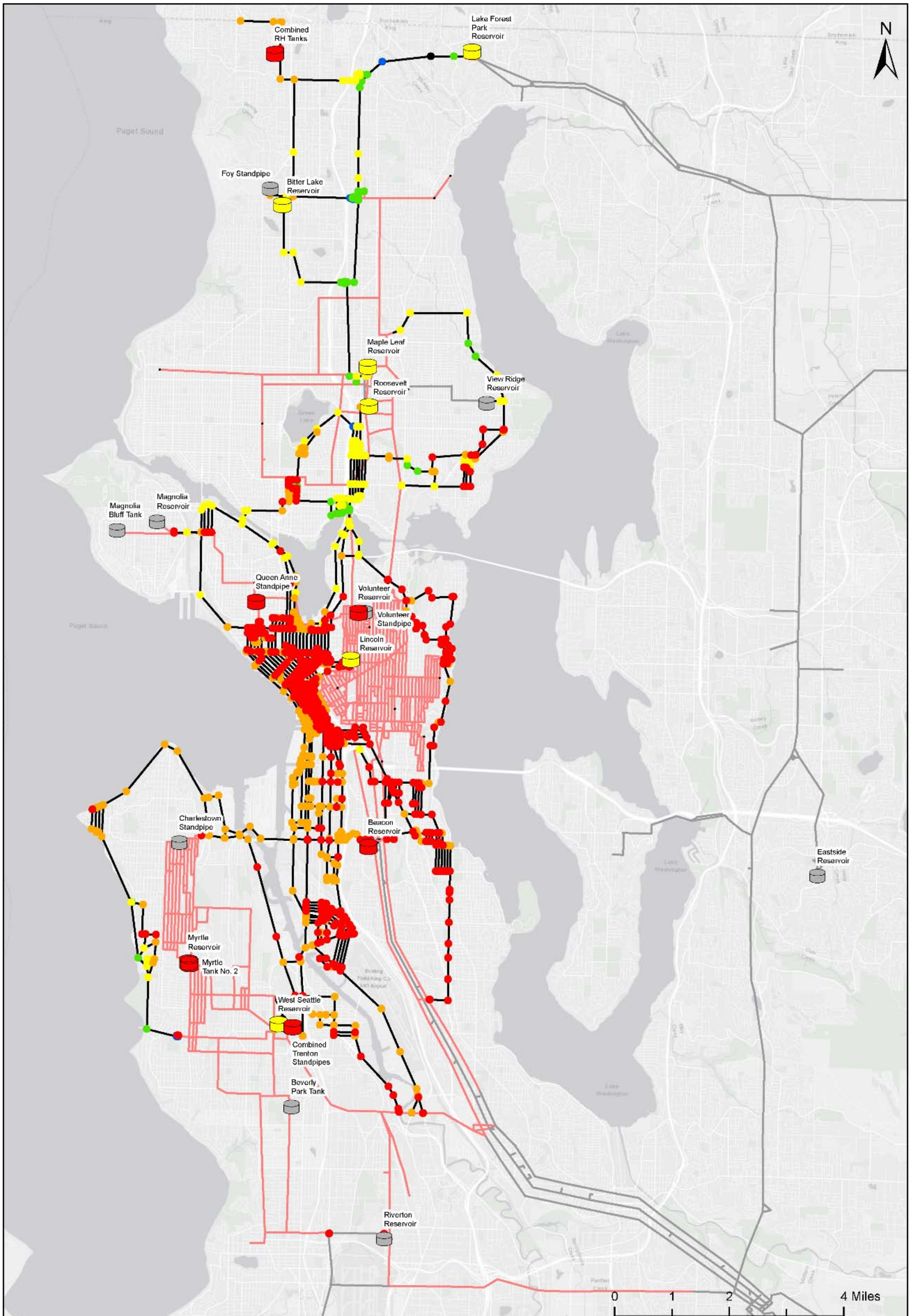
Combined Trenton Standpipes
Boverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 18
8.10

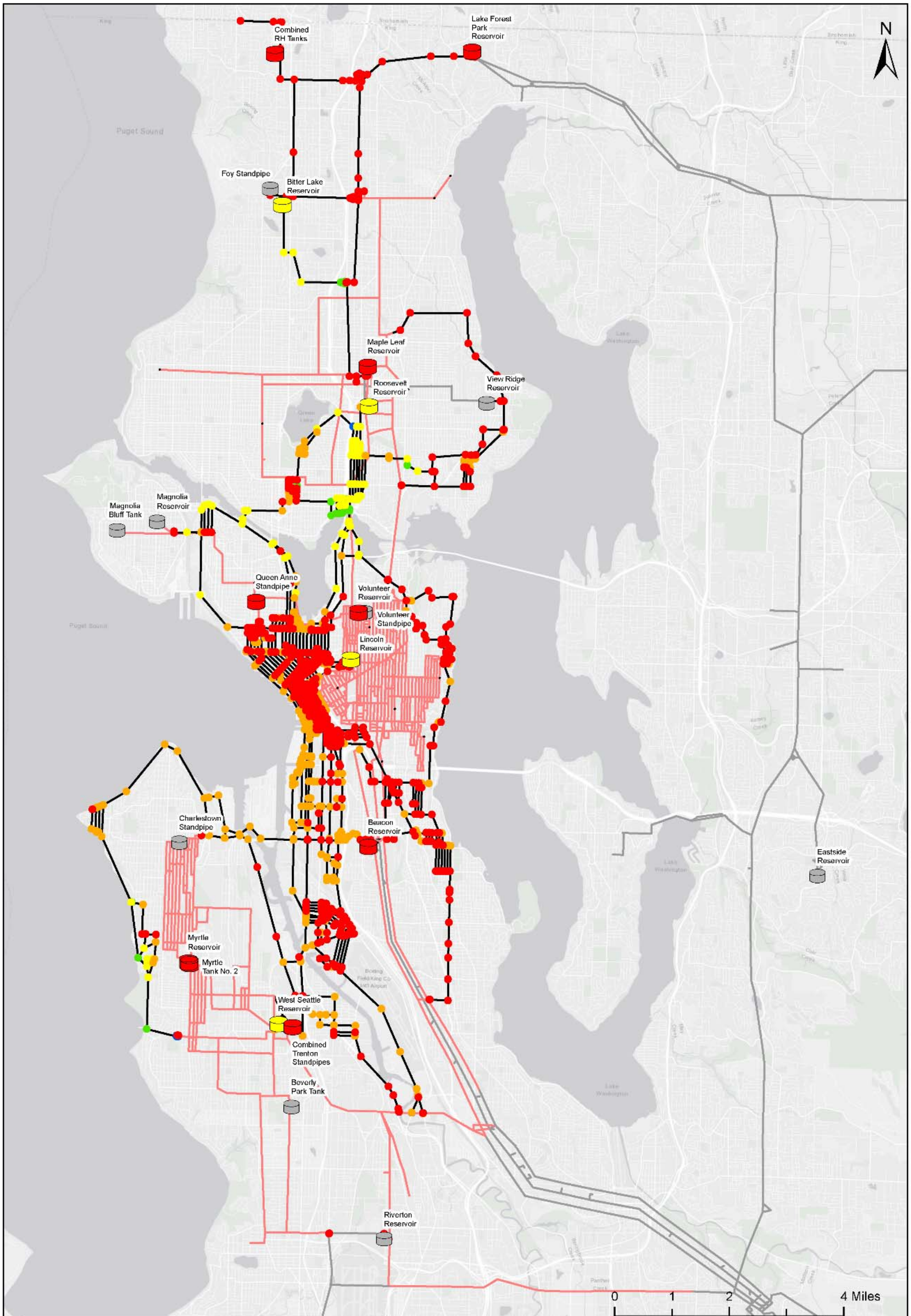


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 20

8.11

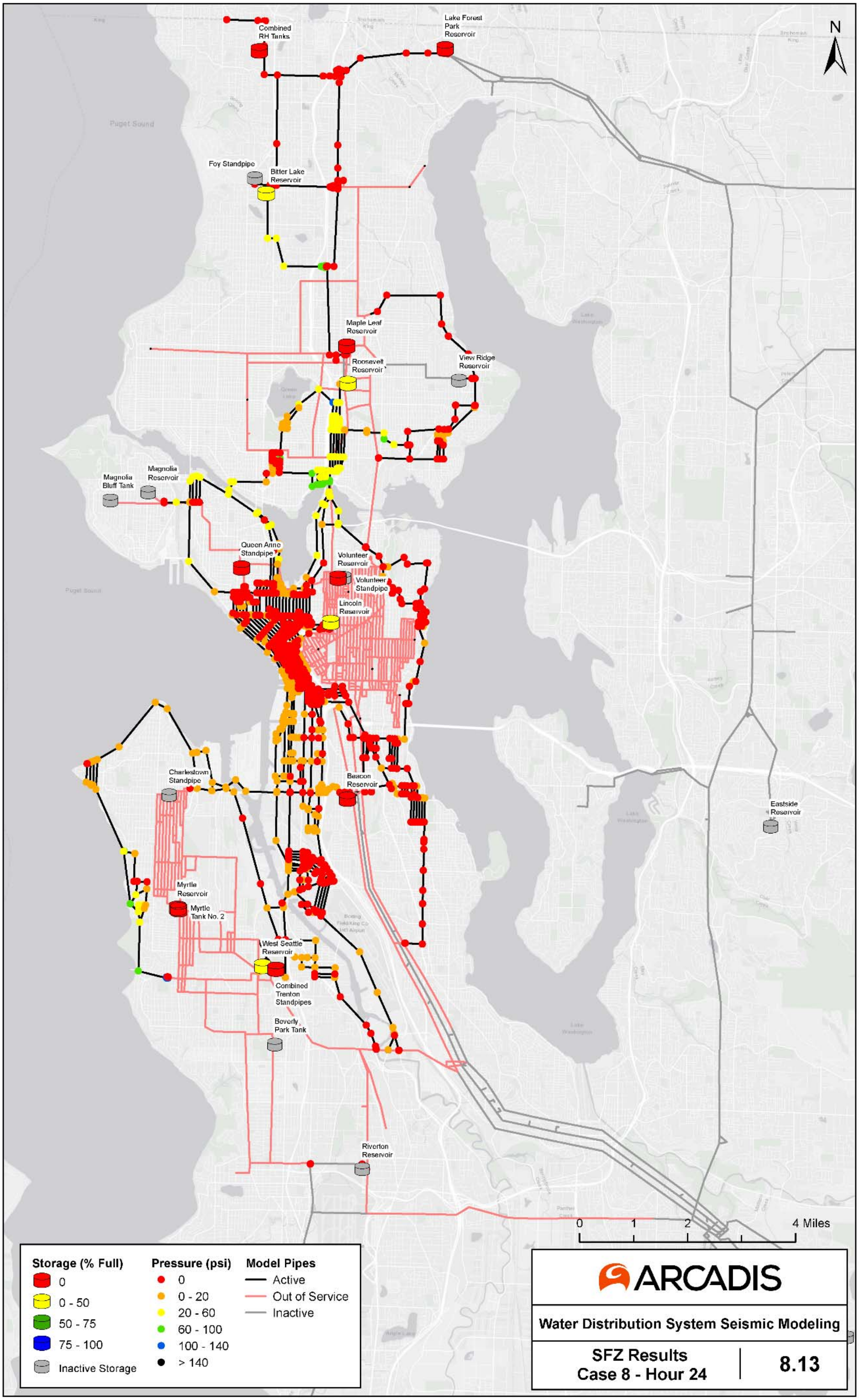


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 22

8.12

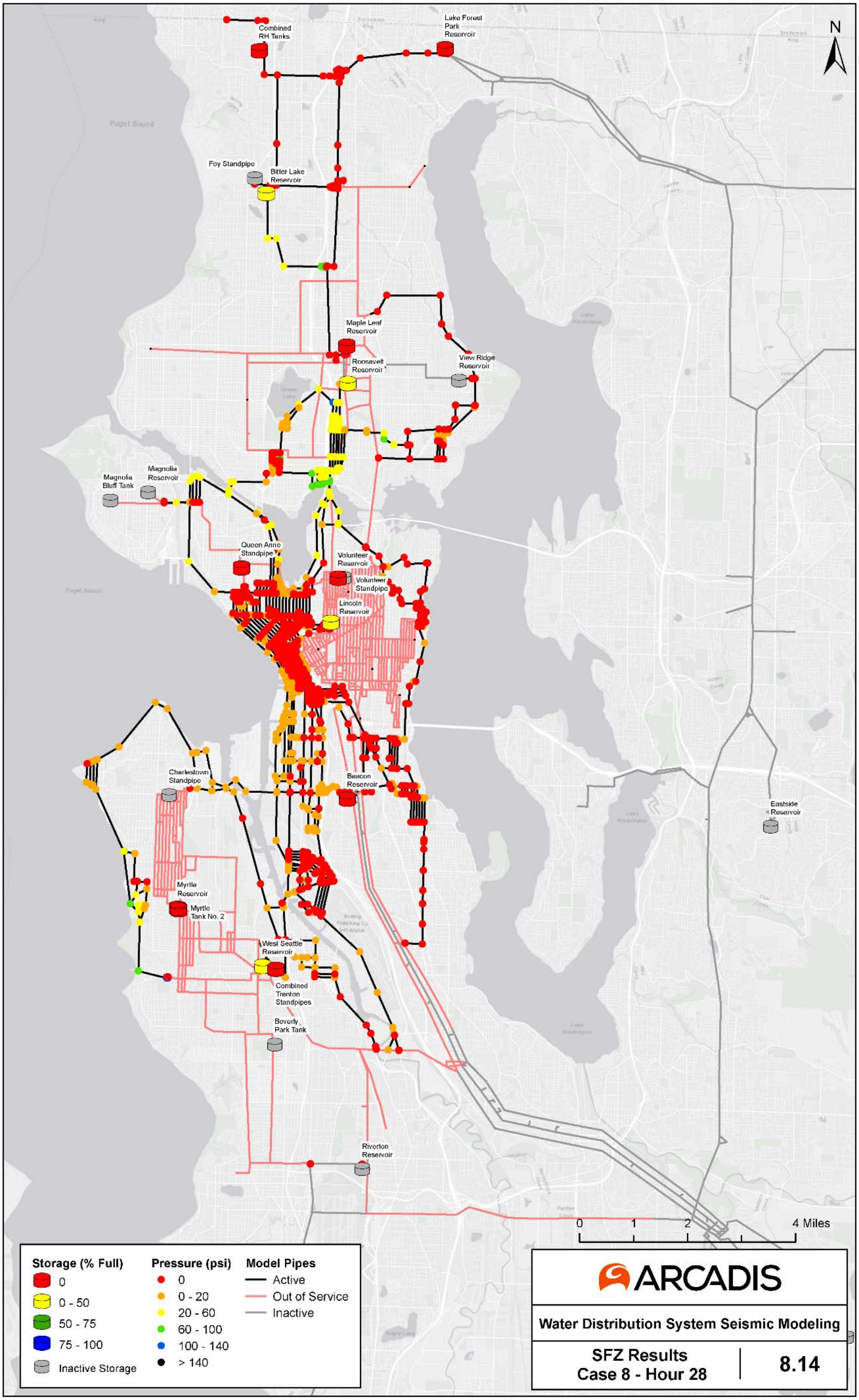


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 24

8.13


Combined RH Tanks
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0
1
2
4 Miles
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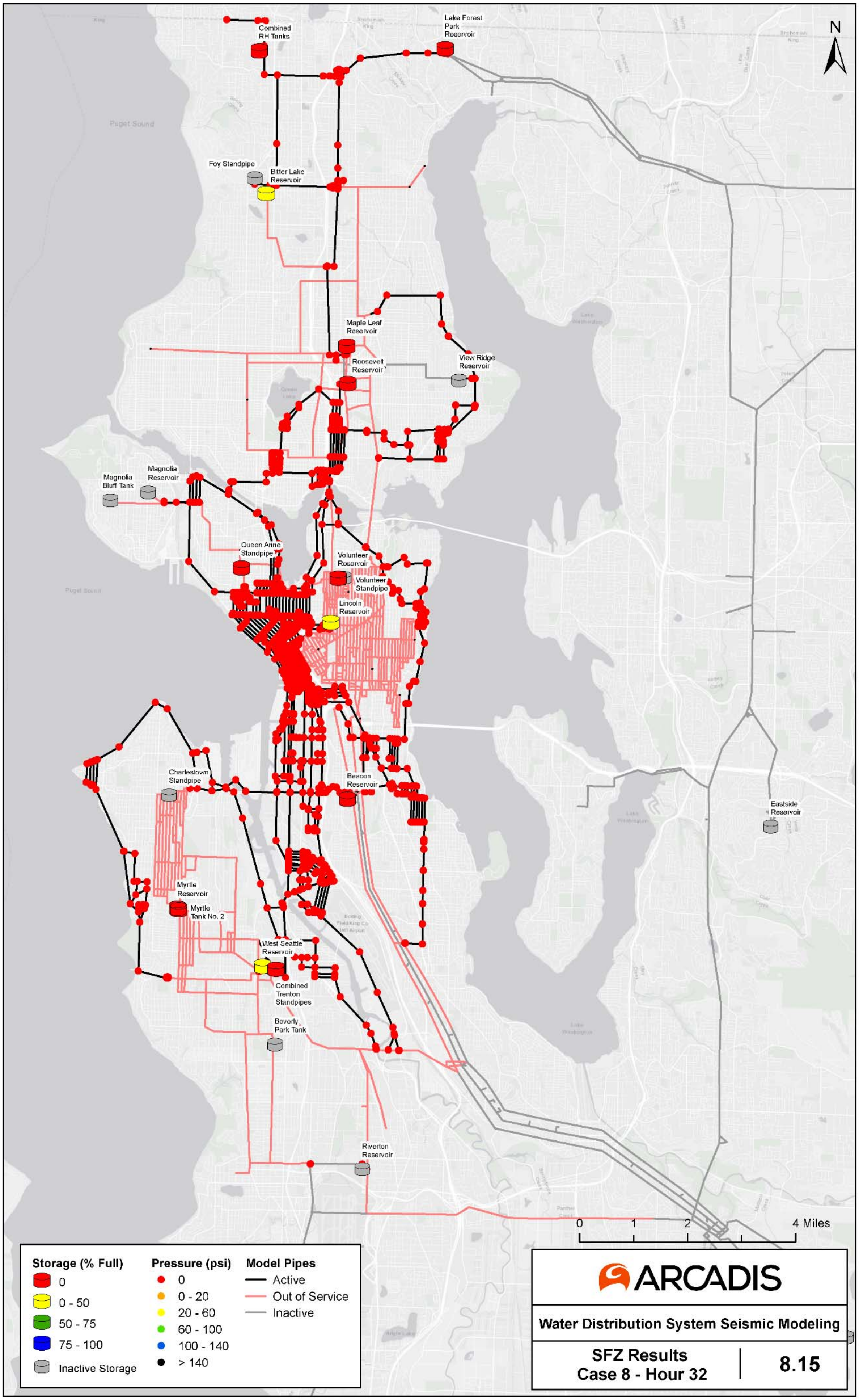
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 28
8.14

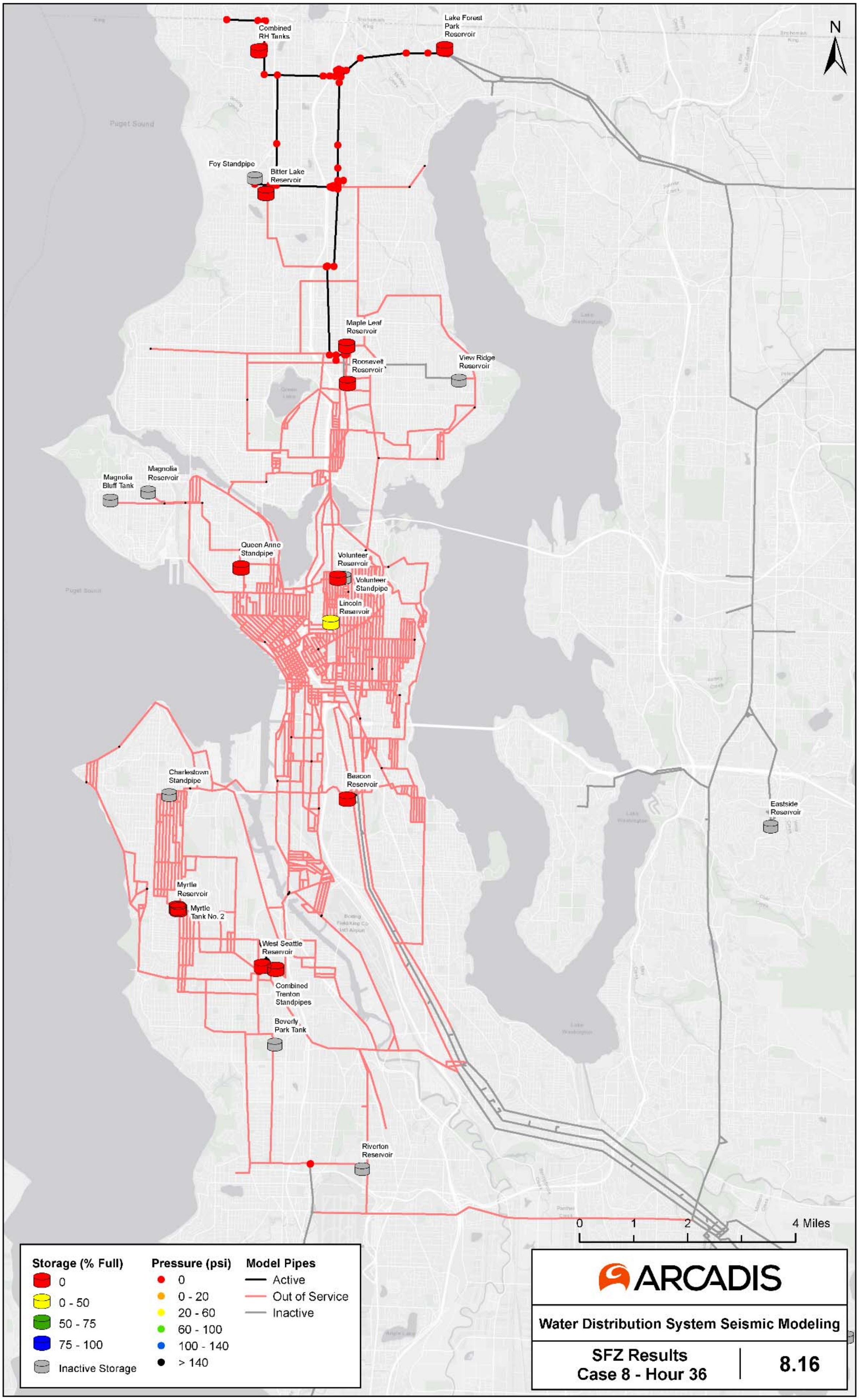


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 32

8.15



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0 1 2 4 Miles
Storage (% Full)
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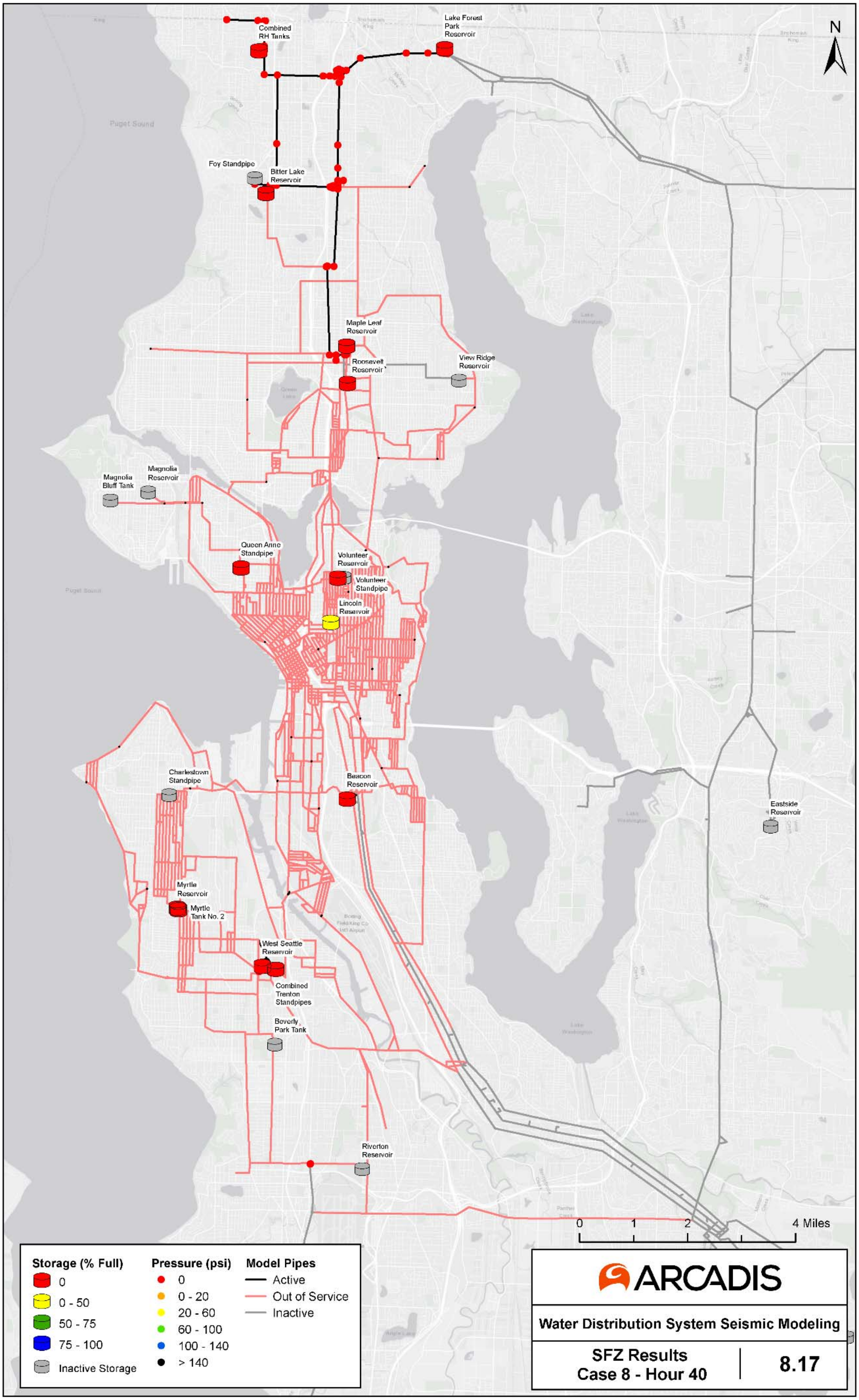
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 36
8.16

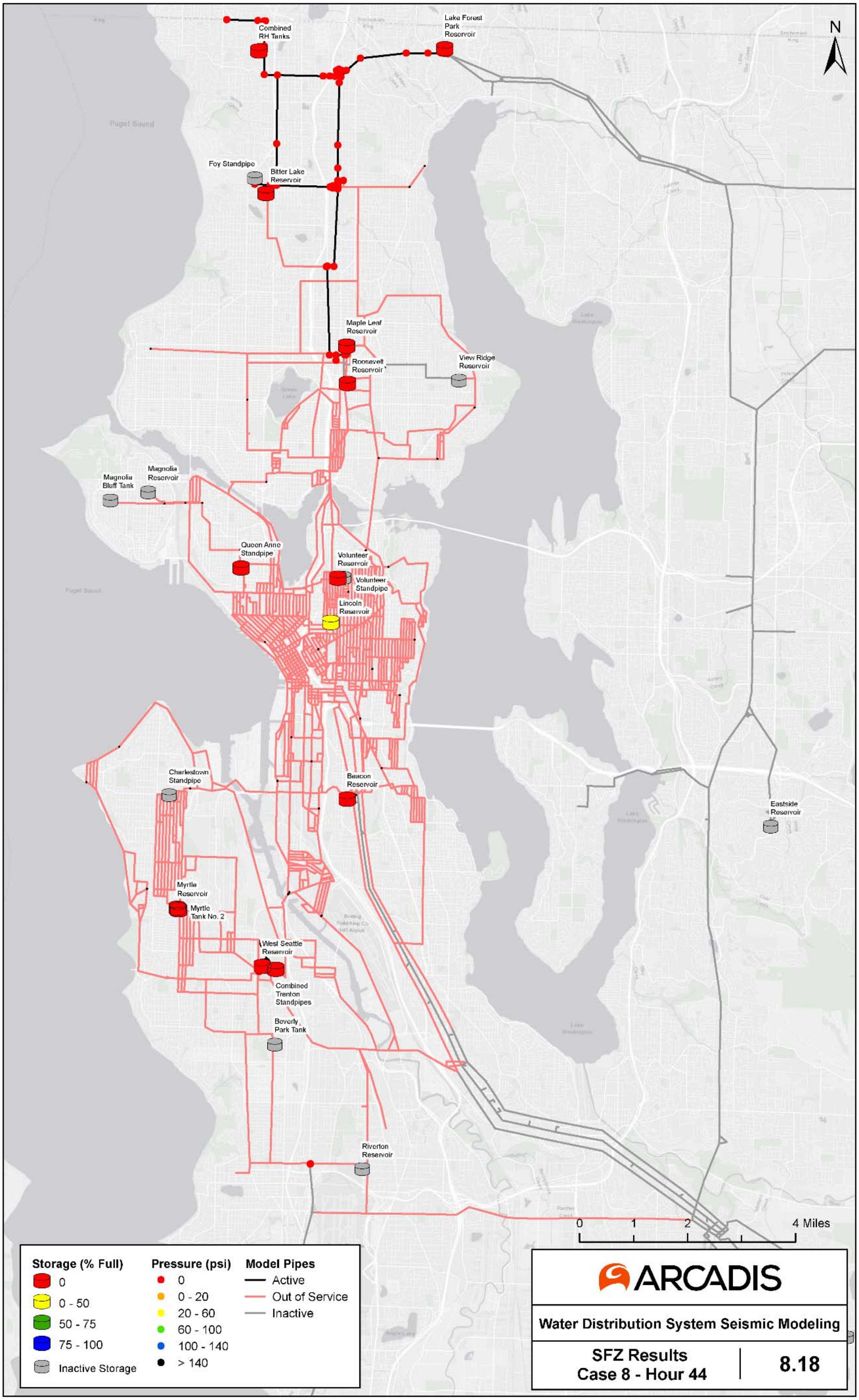


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 40

8.17

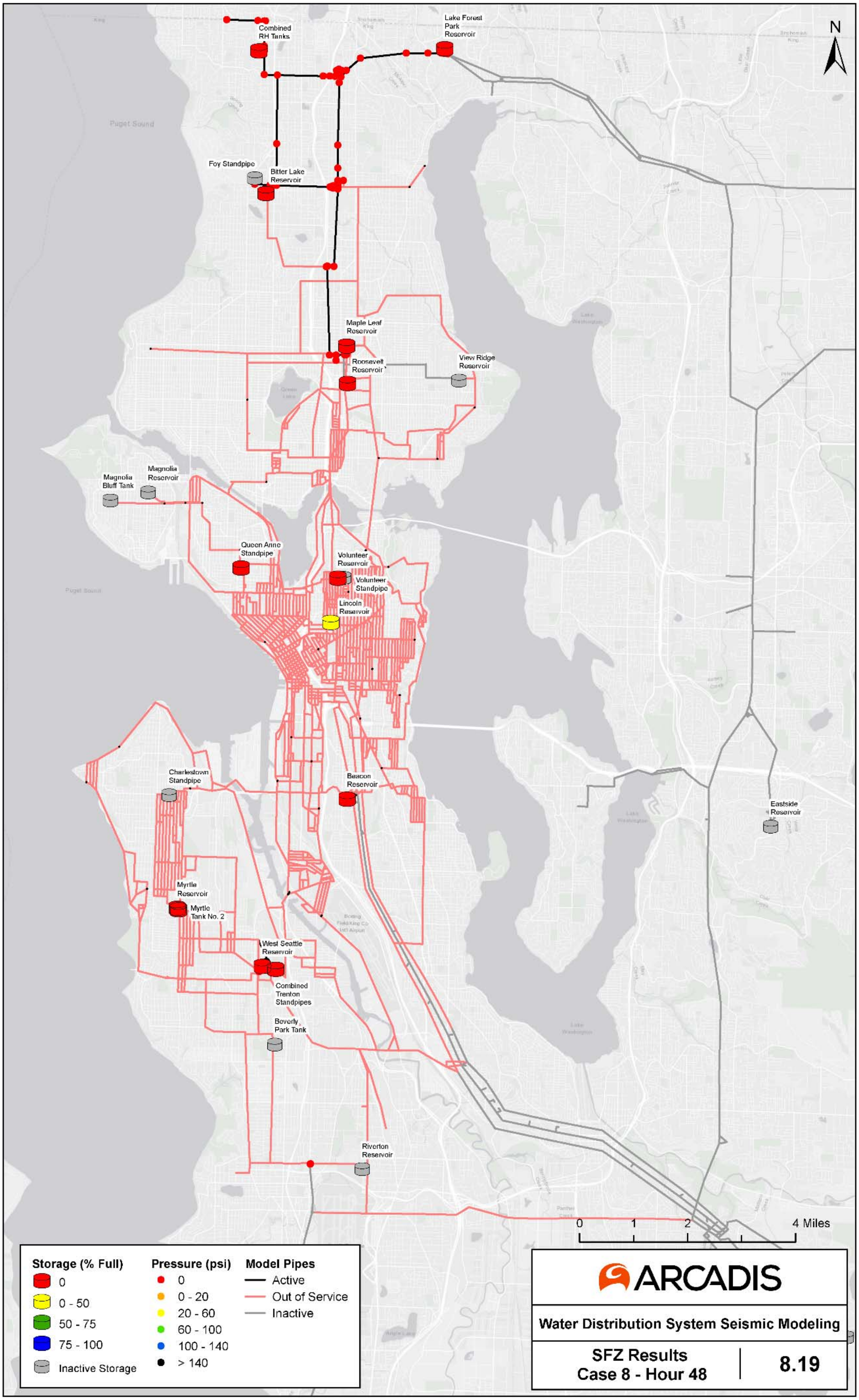


ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 8 - Hour 44

8.18



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Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 8 - Hour 48
8.19

M7.0 Seattle Fault Zone Case 9 (No Improvements Except Tolt Transmission System is Assumed to be Functional and Damage Isolation Systems Have Been Installed) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/6/2018

Seattle Fault Seismic Event

Case 9 Same as Case 7

Assume that certain emitters are now zero and that certain areas are automatically isolated to prevent leakage

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	111,997	89,802	22,195	81%	232.1
3	109,109	87,065	22,044	79%	213.2
12	90,857	74,412	16,445	65%	166.2
22	83,462	67,902	15,560	60%	119.1
32	41,434	35,937	5,498	25%	95.0
48	41,137	35,639	5,498	24%	61.6

Model Regions Forced Out of Service During Simulation

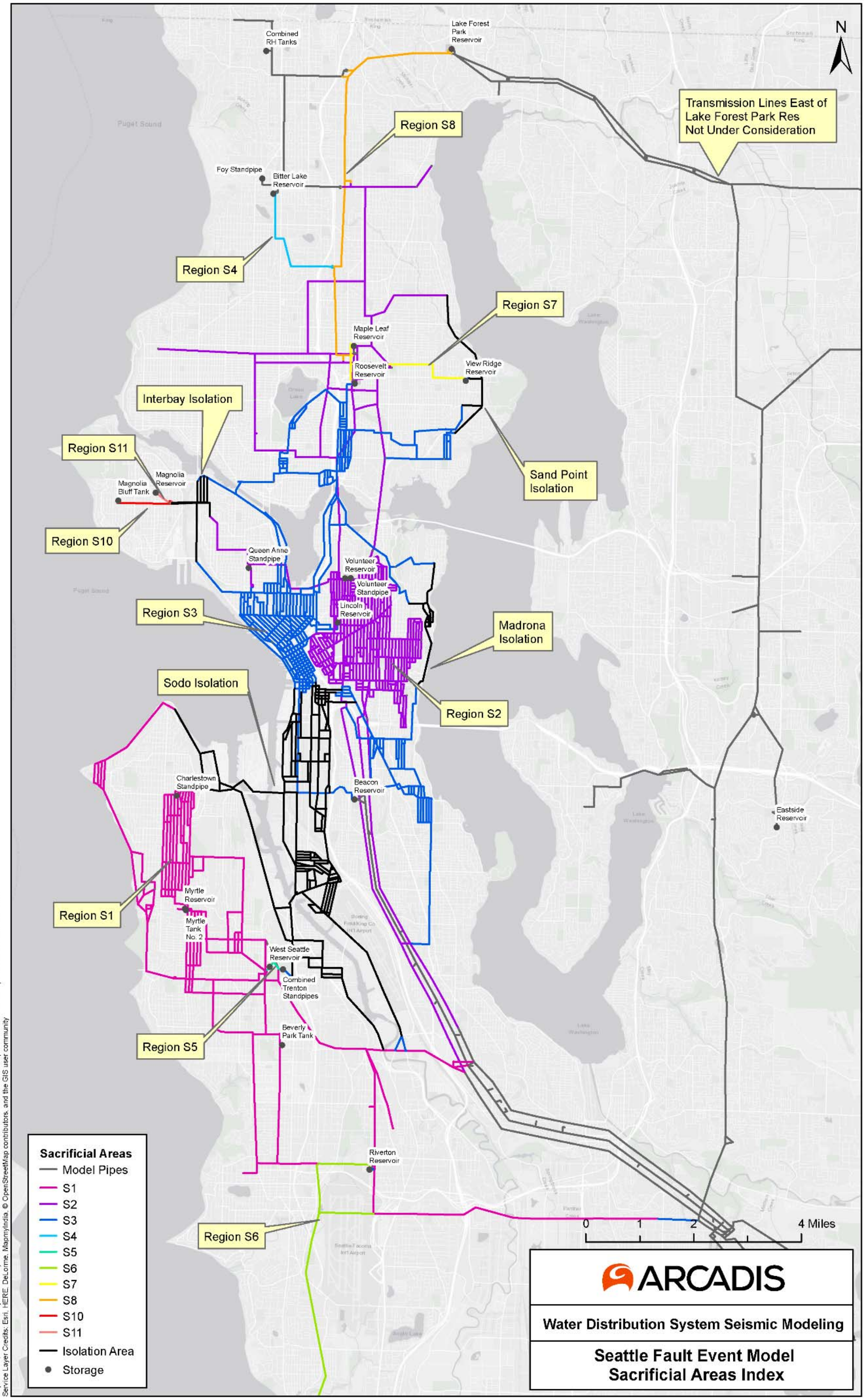
Time	Region
6	S1
23	S2

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 9.1	Hr 0	Fig. 9.5	Hr 8	Fig. 9.9	Hr 16	Fig. 9.13	Hr 24	Fig. 9.17	Hr 40
Fig. 9.2	Hr 2	Fig. 9.6	Hr 10	Fig. 9.10	Hr 18	Fig. 9.14	Hr 28	Fig. 9.18	Hr 44
Fig. 9.3	Hr 4	Fig. 9.7	Hr 12	Fig. 9.11	Hr 20	Fig. 9.15	Hr 32	Fig. 9.19	Hr 48
Fig. 9.4	Hr 6	Fig. 9.8	Hr 14	Fig. 9.12	Hr 22	Fig. 9.16	Hr 36		



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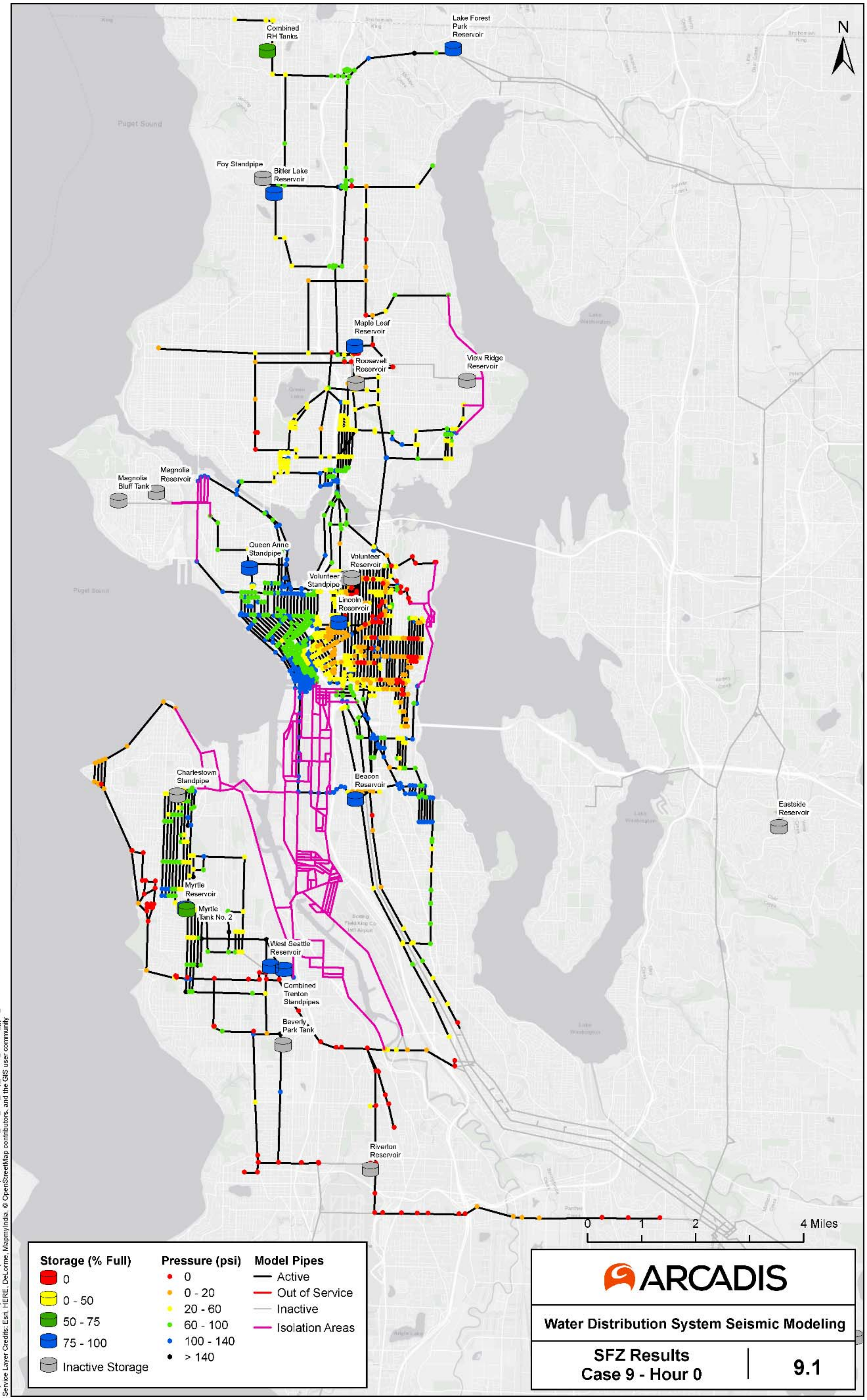

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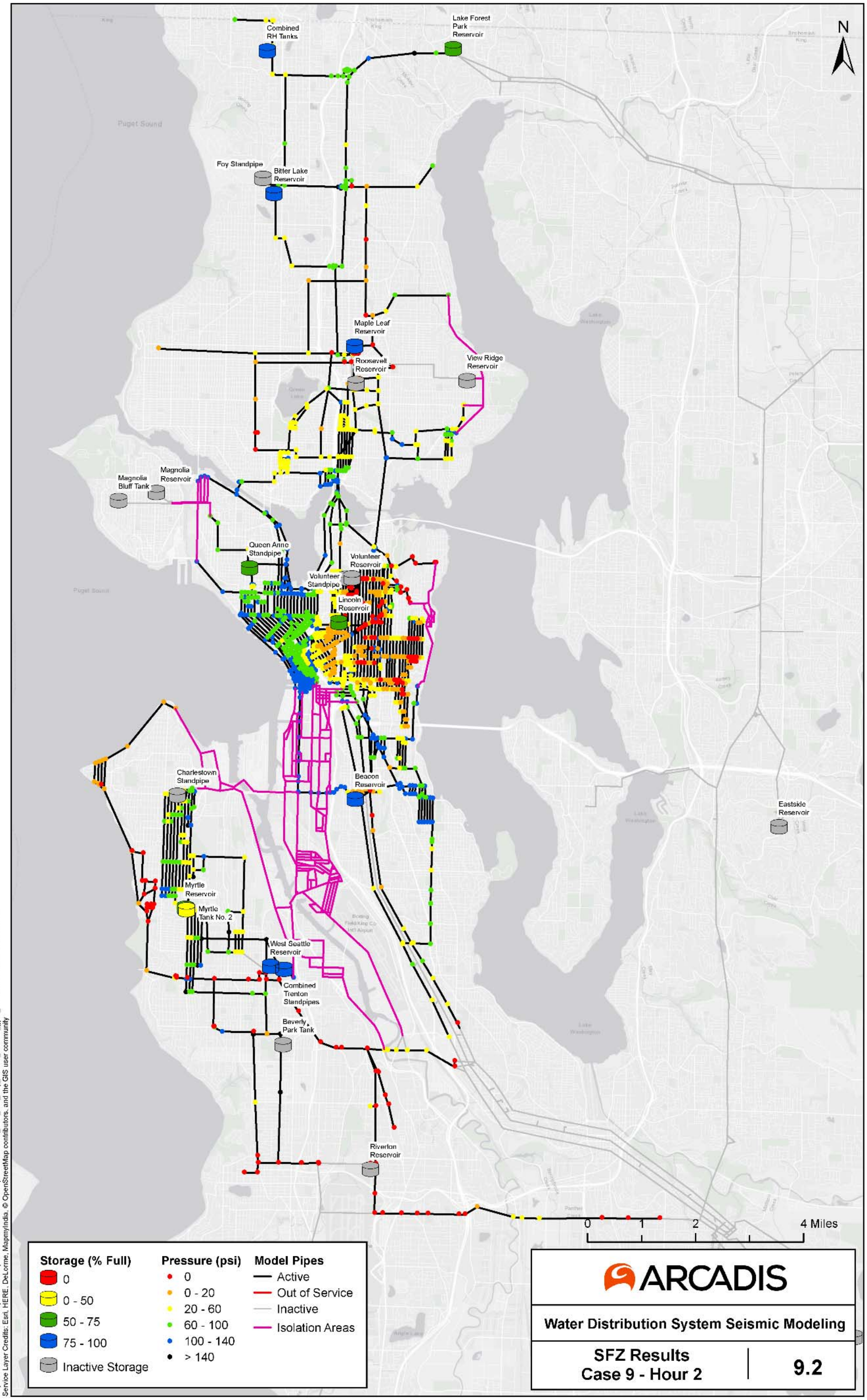

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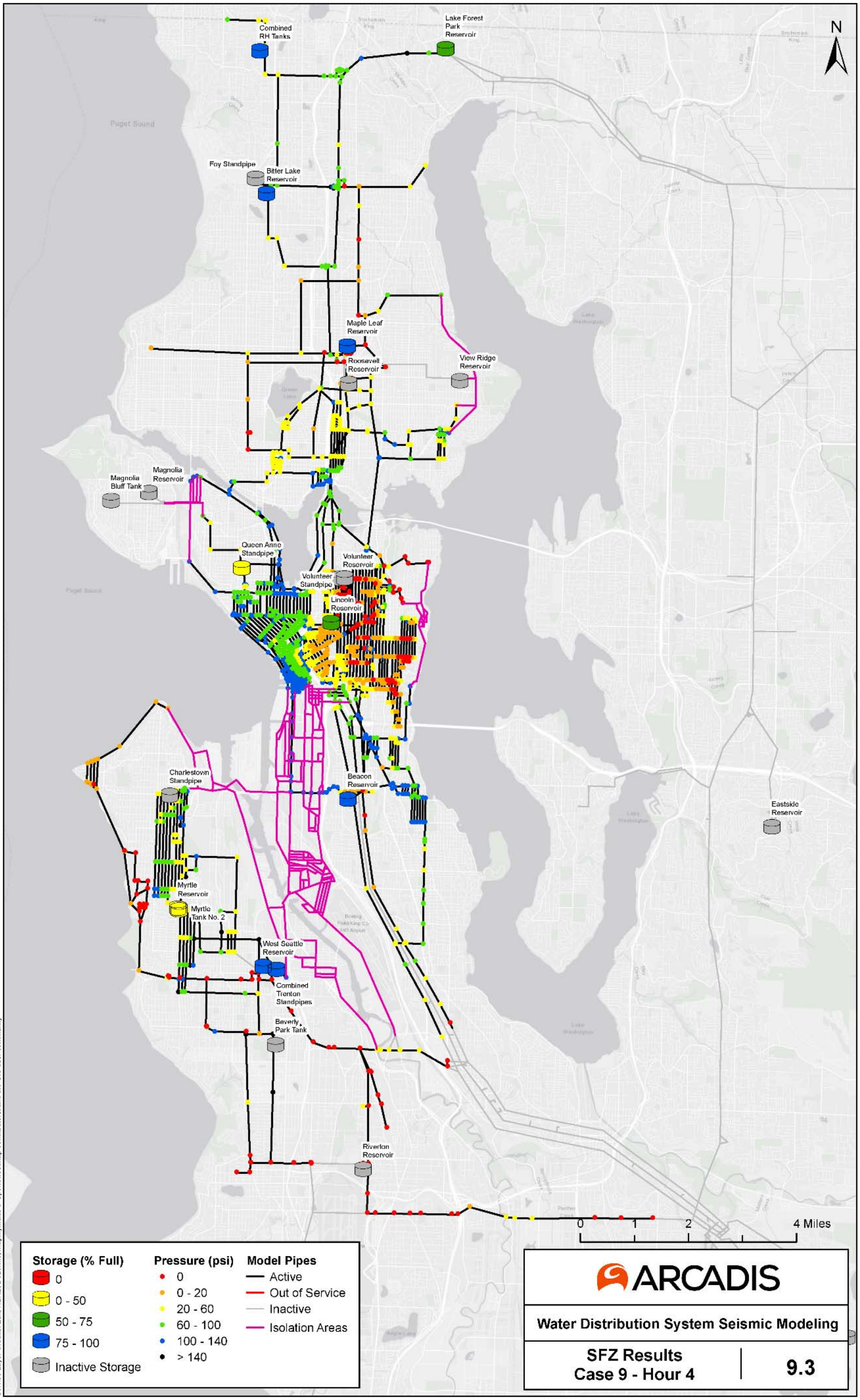

Water Distribution System Seismic Modeling

SFZ Results
Case 9 - Hour 4

9.3

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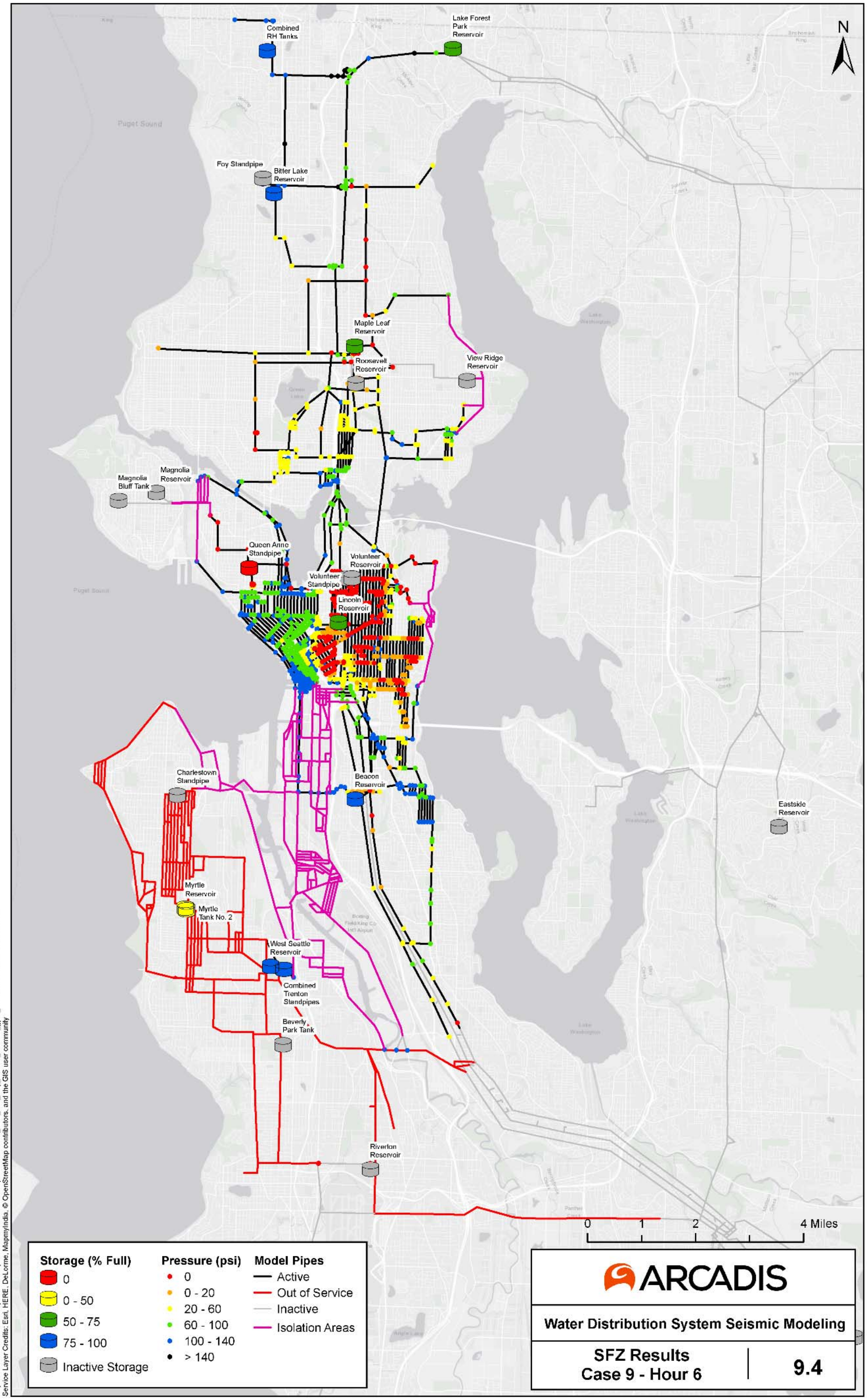

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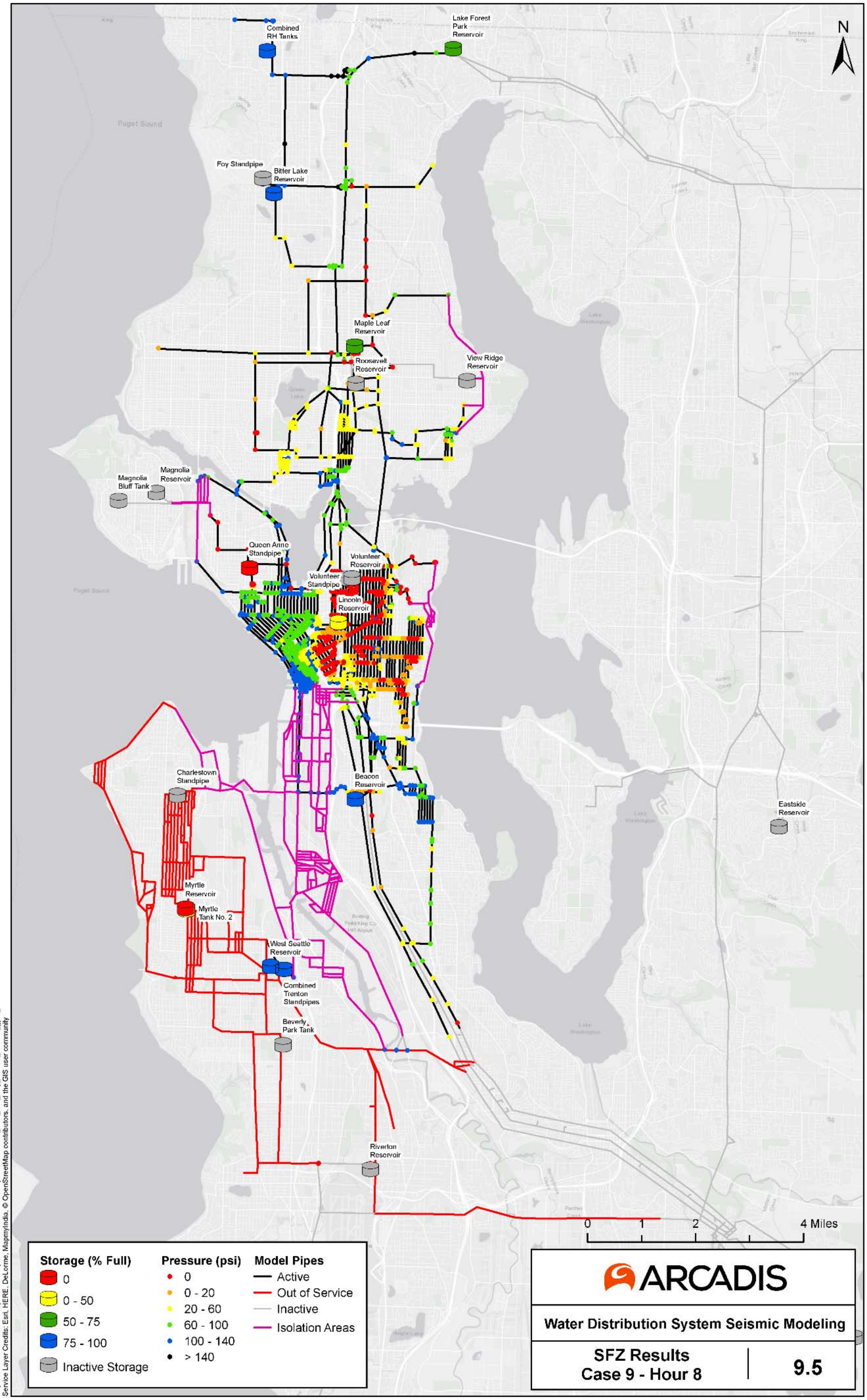

Water Distribution System Seismic Modeling

SFZ Results
Case 9 - Hour 8

9.5

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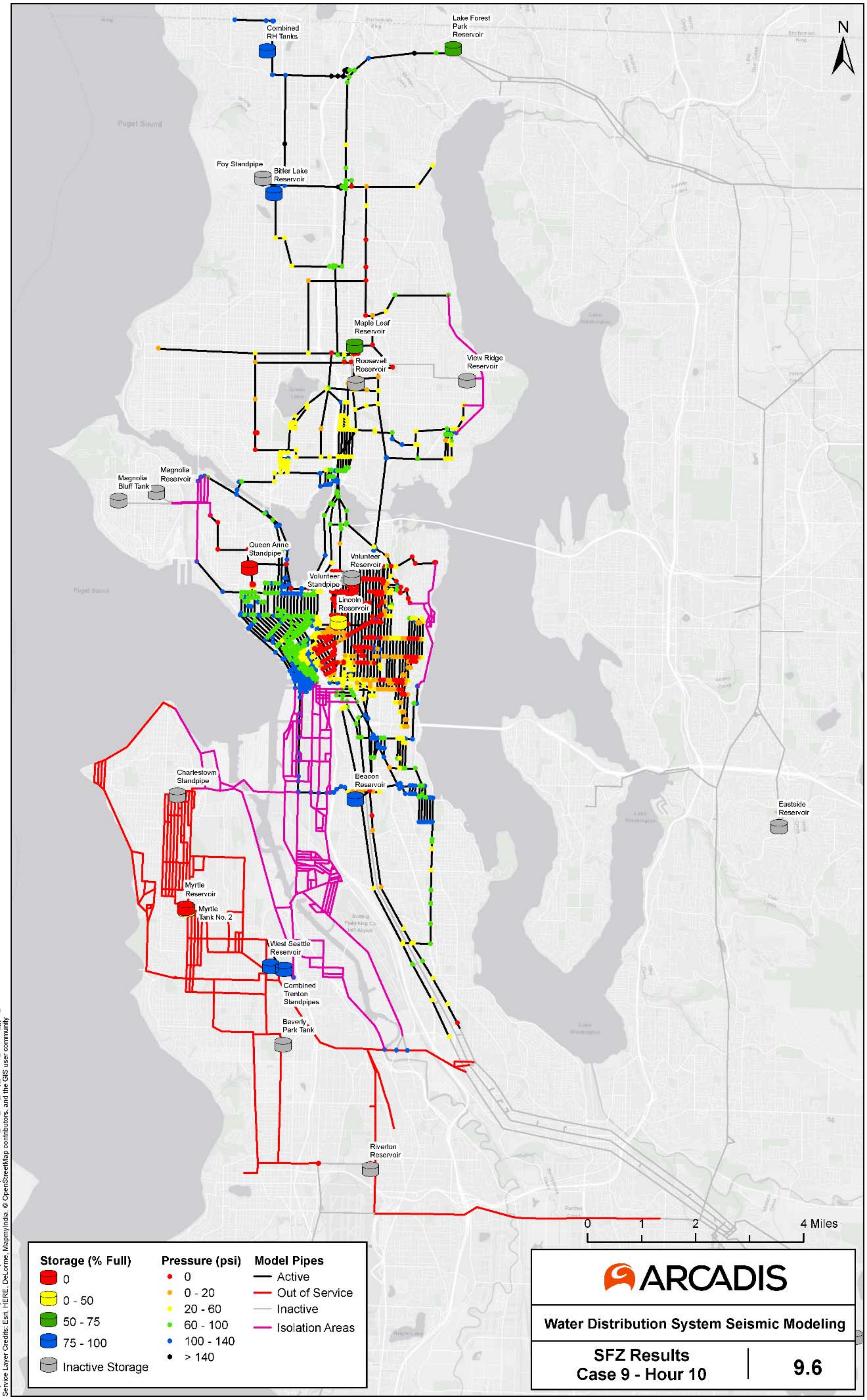

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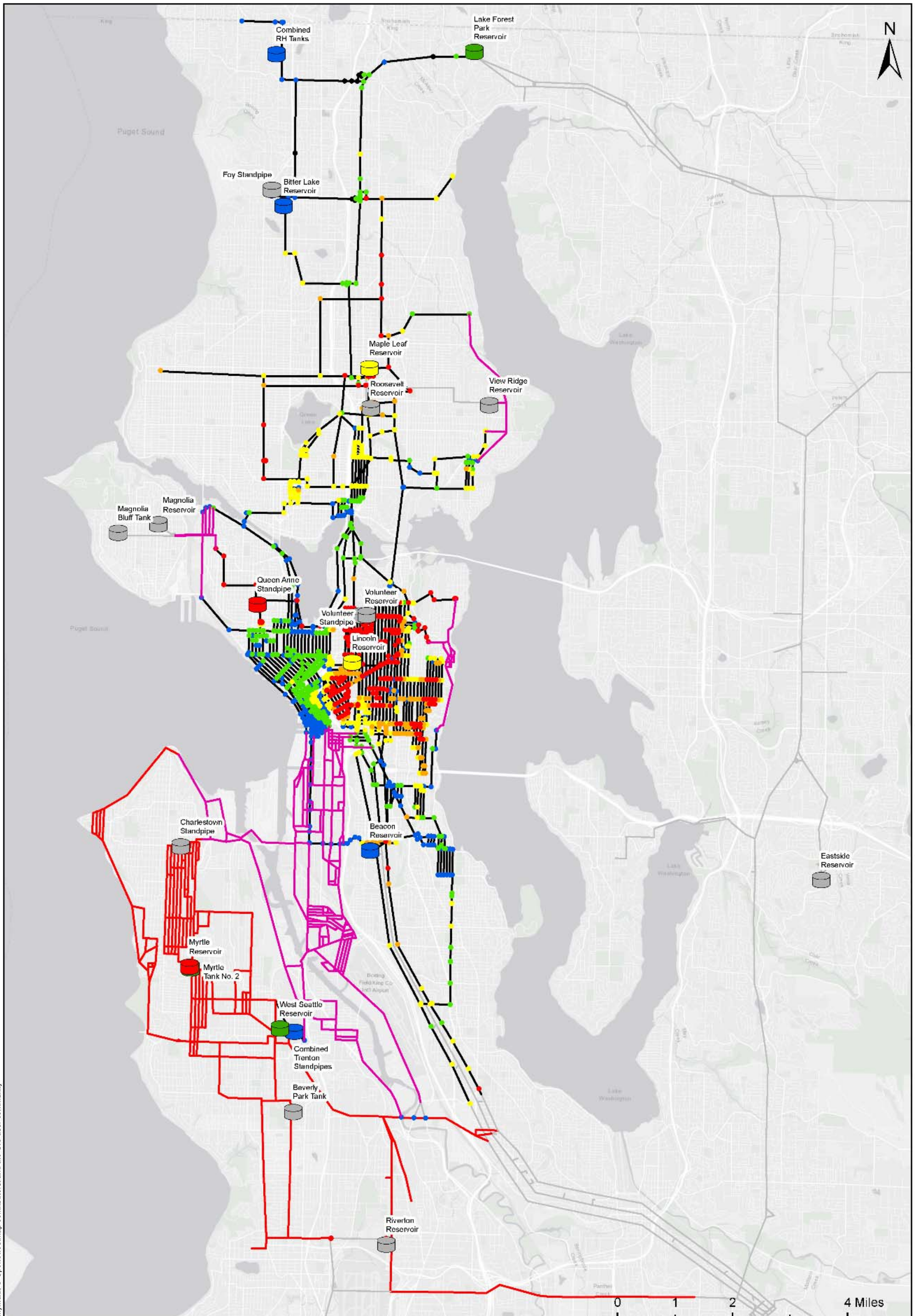
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 9 - Hour 12

9.7

City: Seattle, WA Created By: bchenevey C:\Users\DMann\Desktop\Seattle\SSRA_SFZ_Min_Day_168hrs_011918_gpm_res.mxd 1/19/2018 8:48:51 AM
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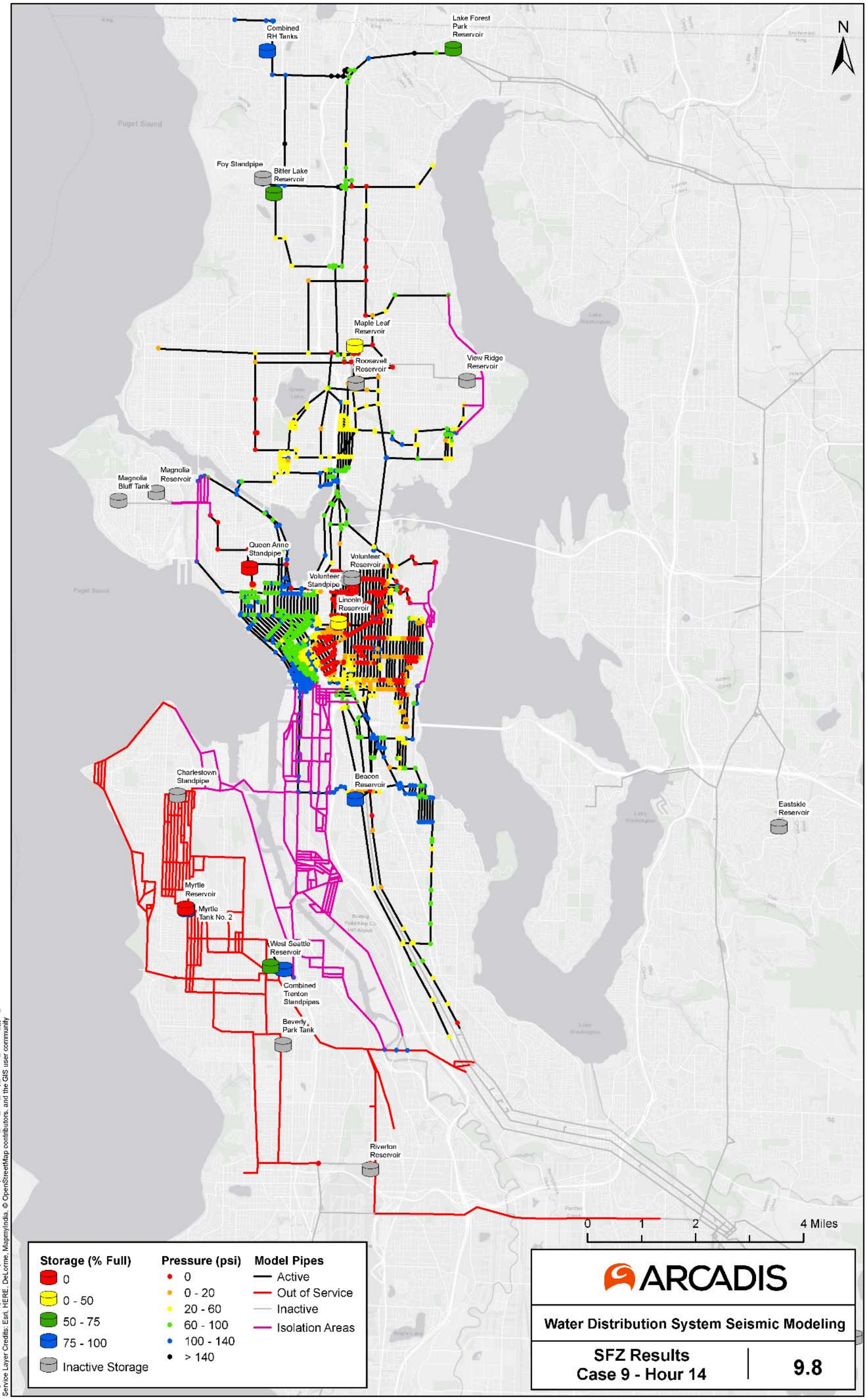

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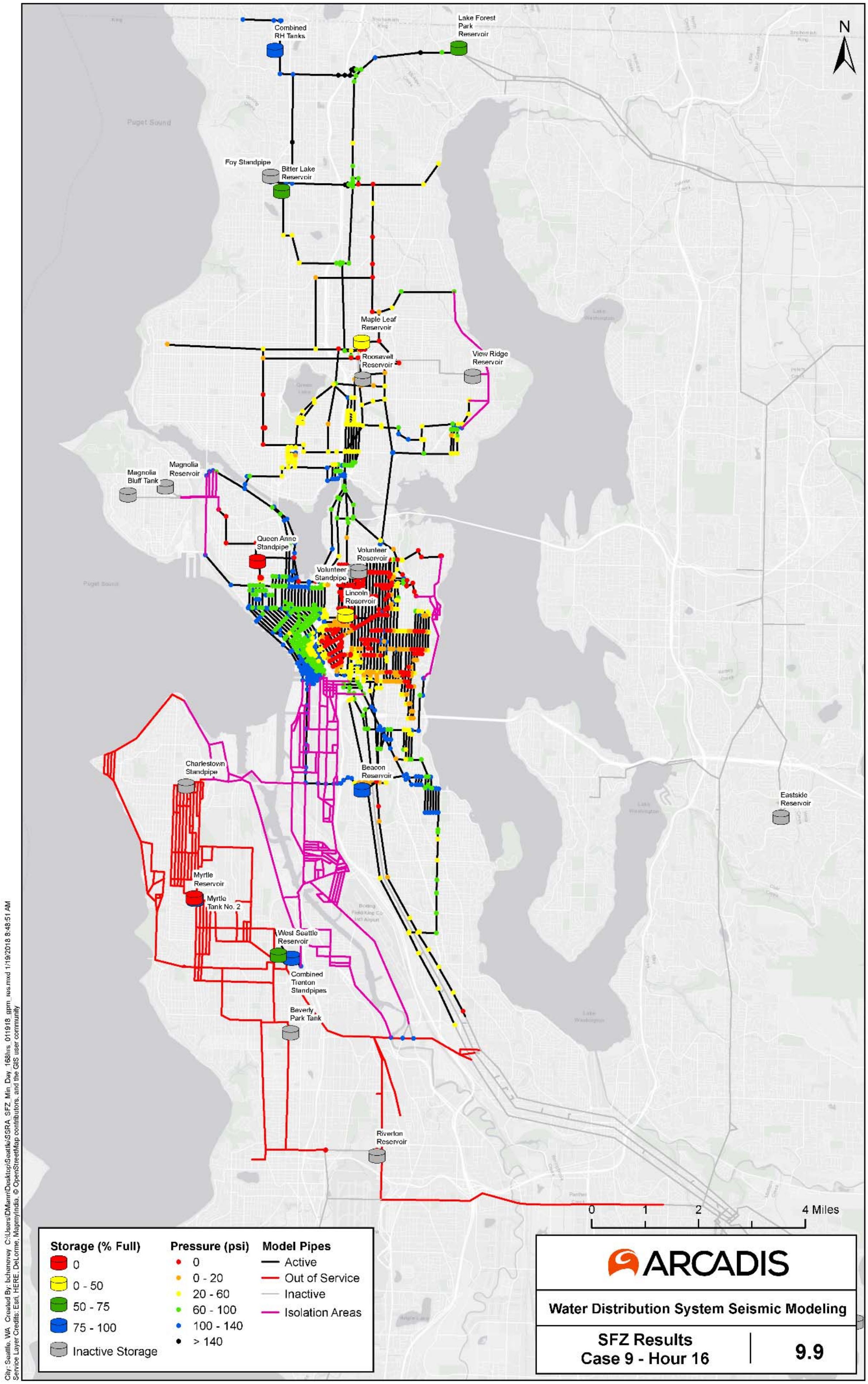
Combined RH Tanks
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Puget Sound
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Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
West Seattle Reservoir
Combined Trenton Standpipes
Beverly Park Tank
Riverton Reservoir
0 1 2 4 Miles
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Model Pipes
Active
Out of Service
Inactive
Isolation Areas
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 9 - Hour 16
9.9
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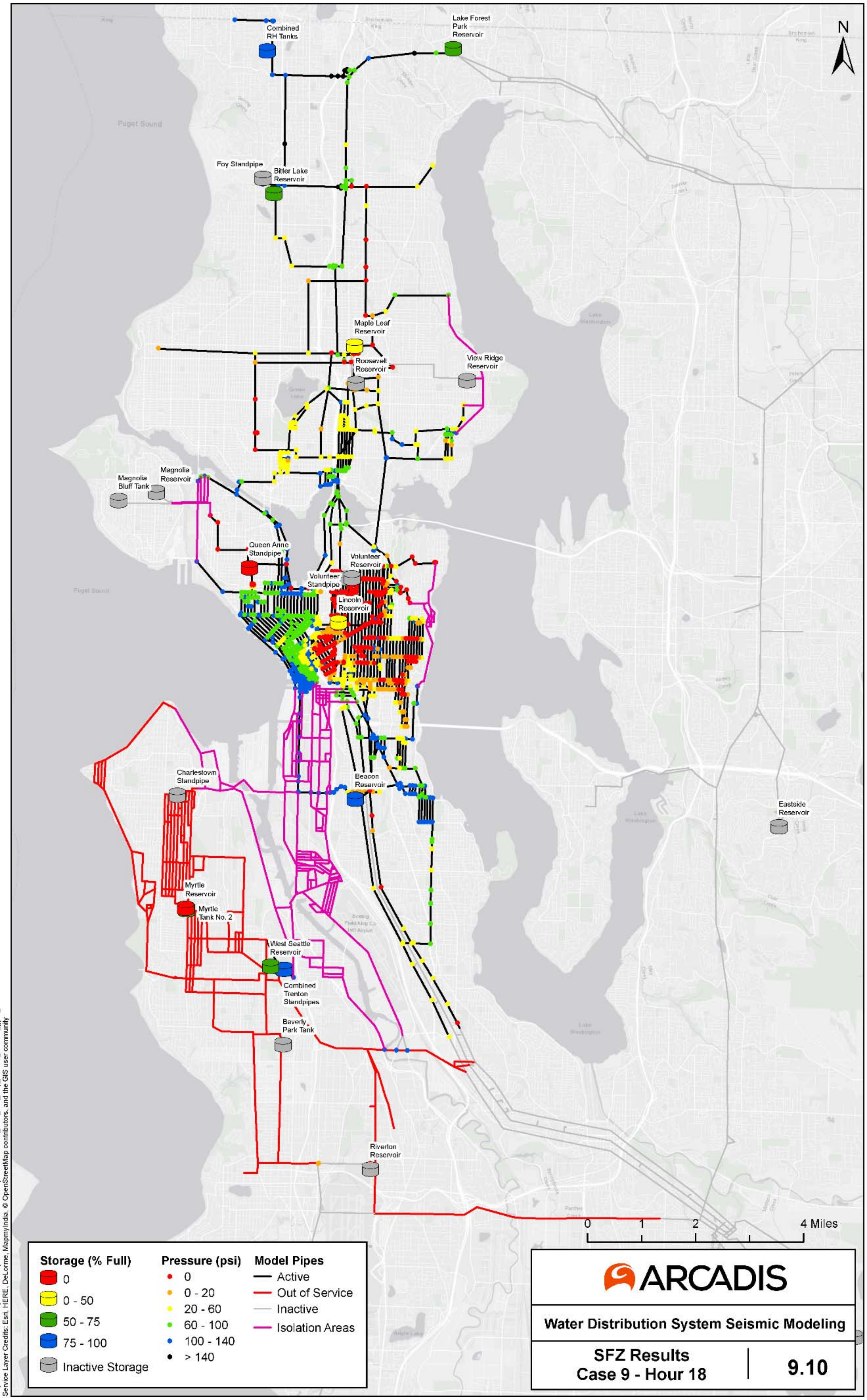

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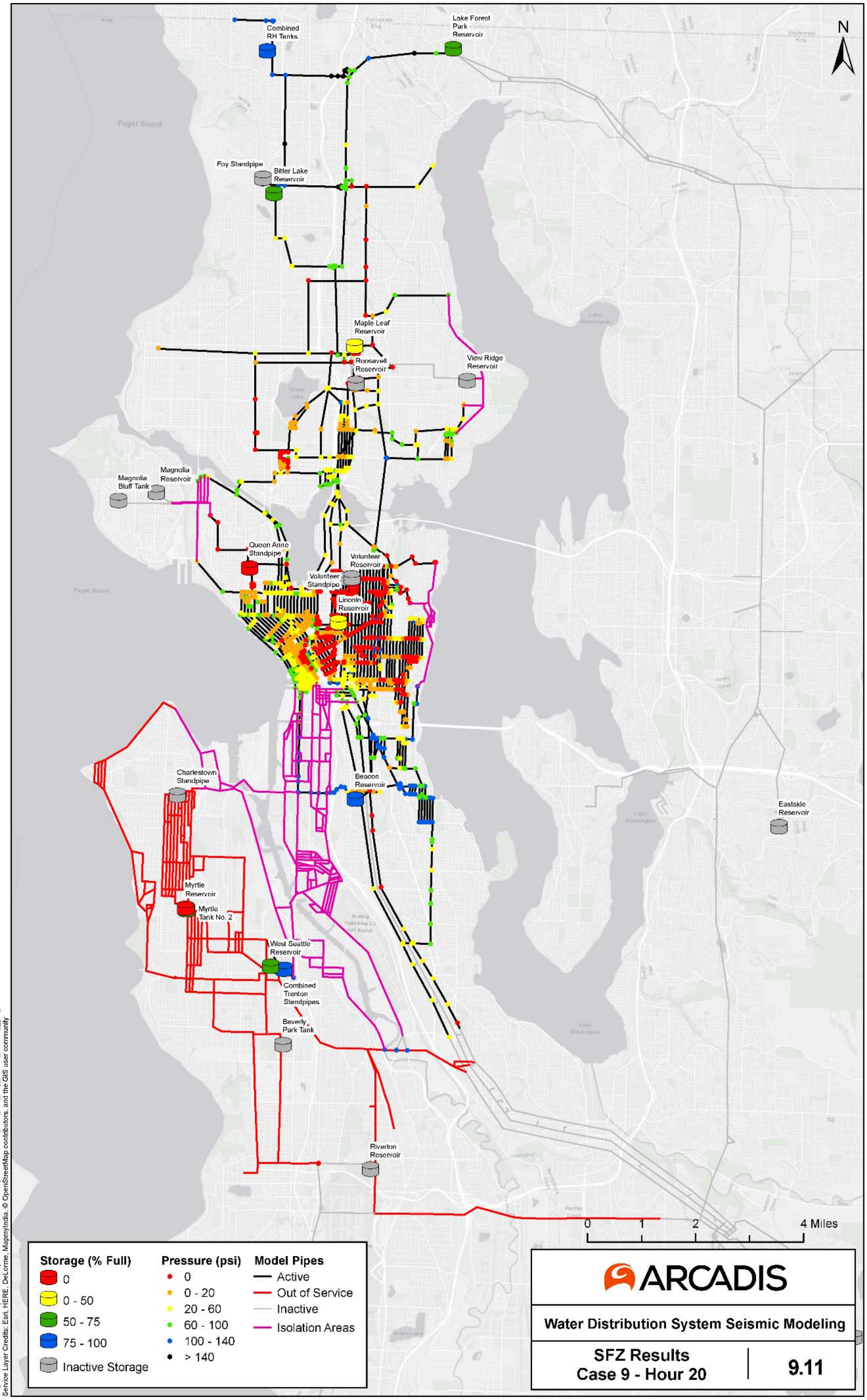

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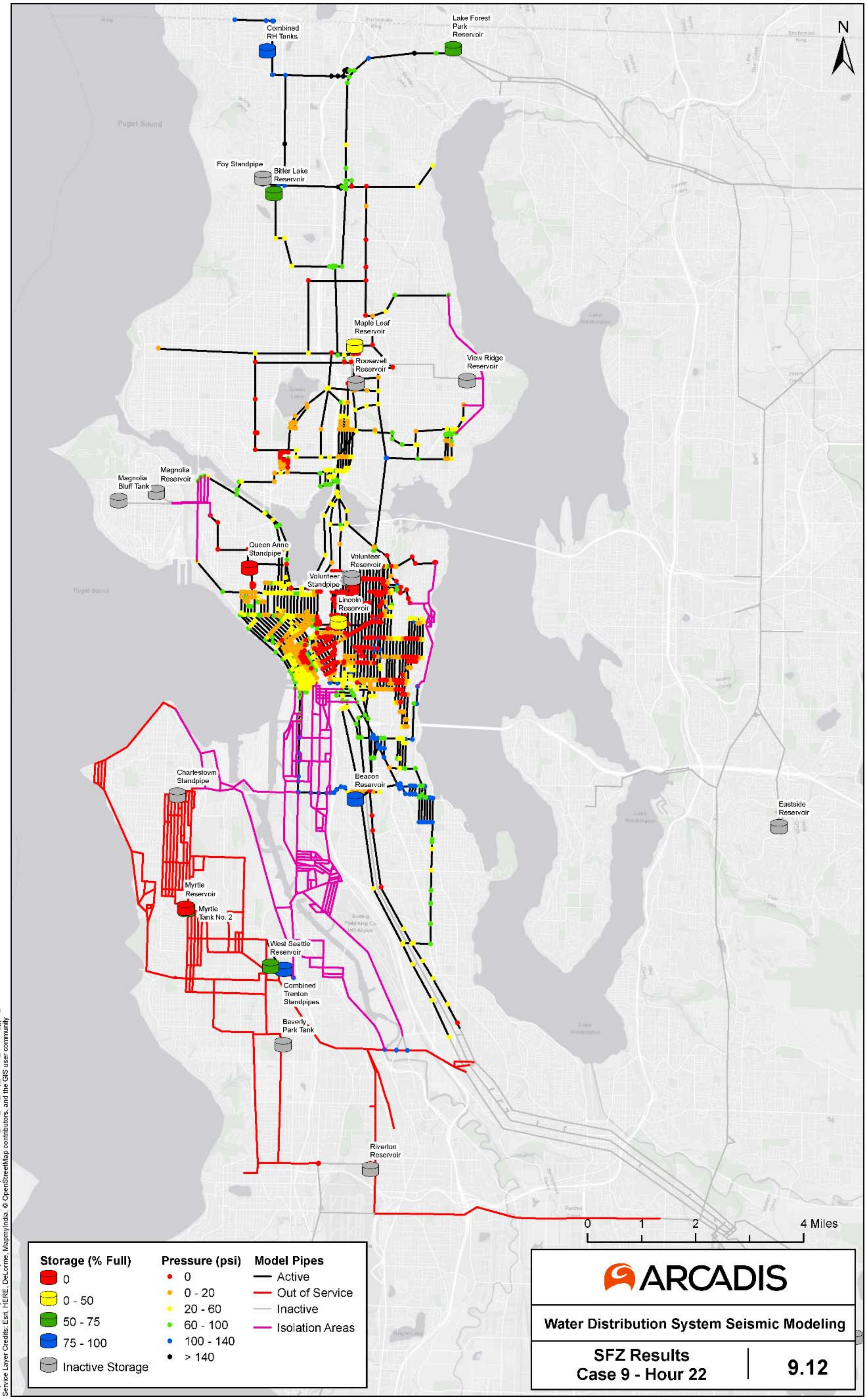

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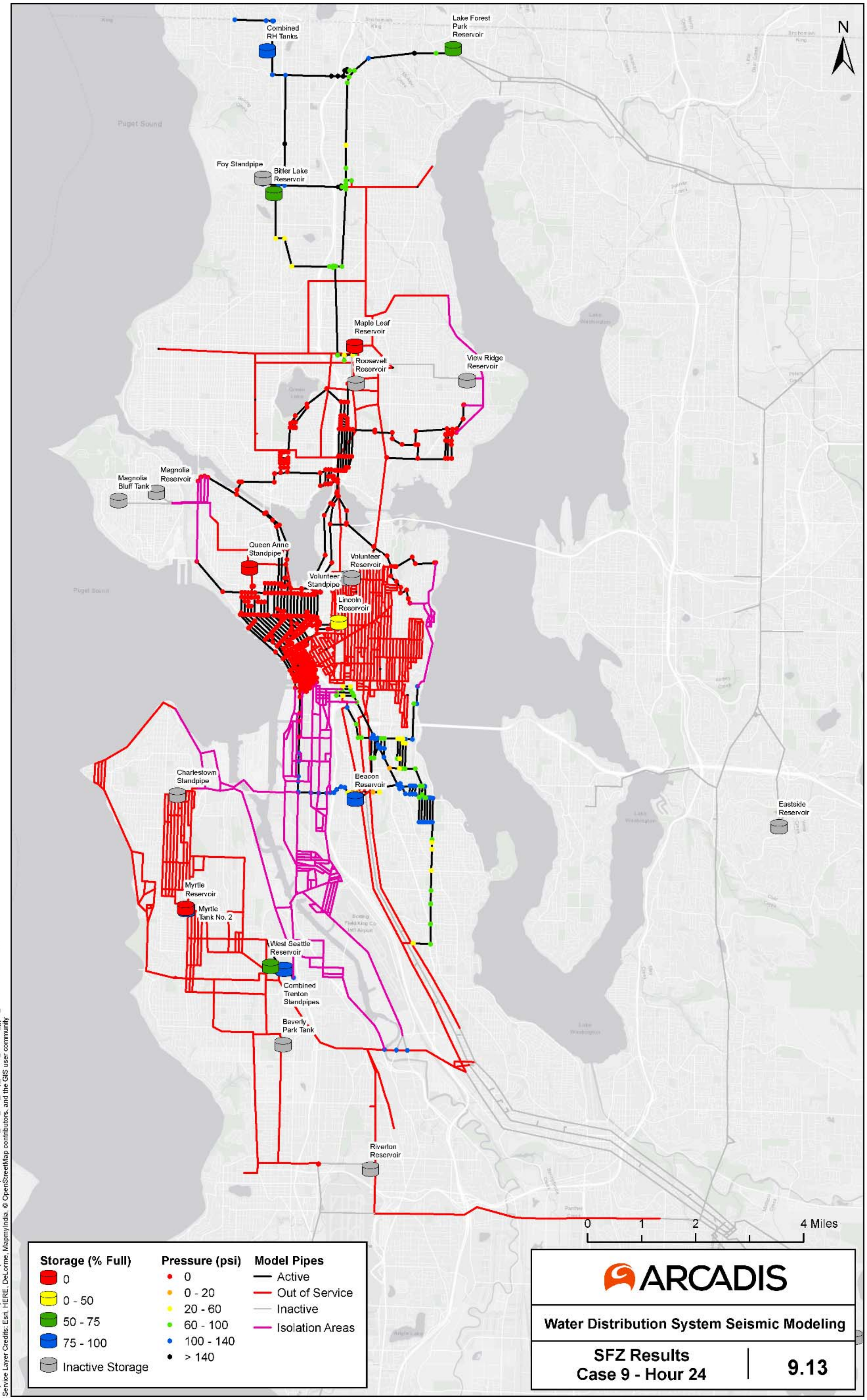

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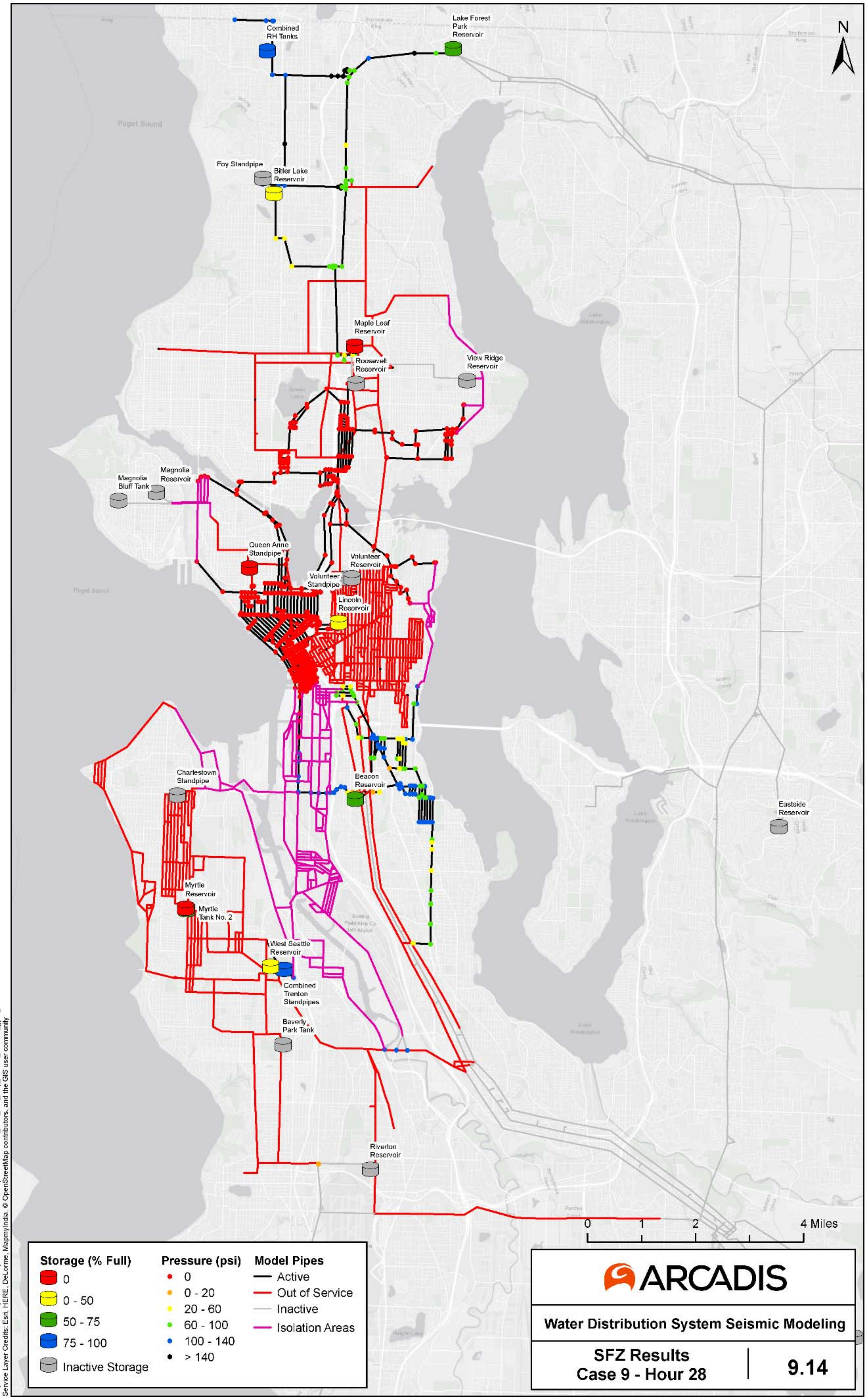

N
Combined RH Tanks
Lake Forest Park Reservoir
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Foy Standpipe
Bitter Lake Reservoir
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> 140
Model Pipes
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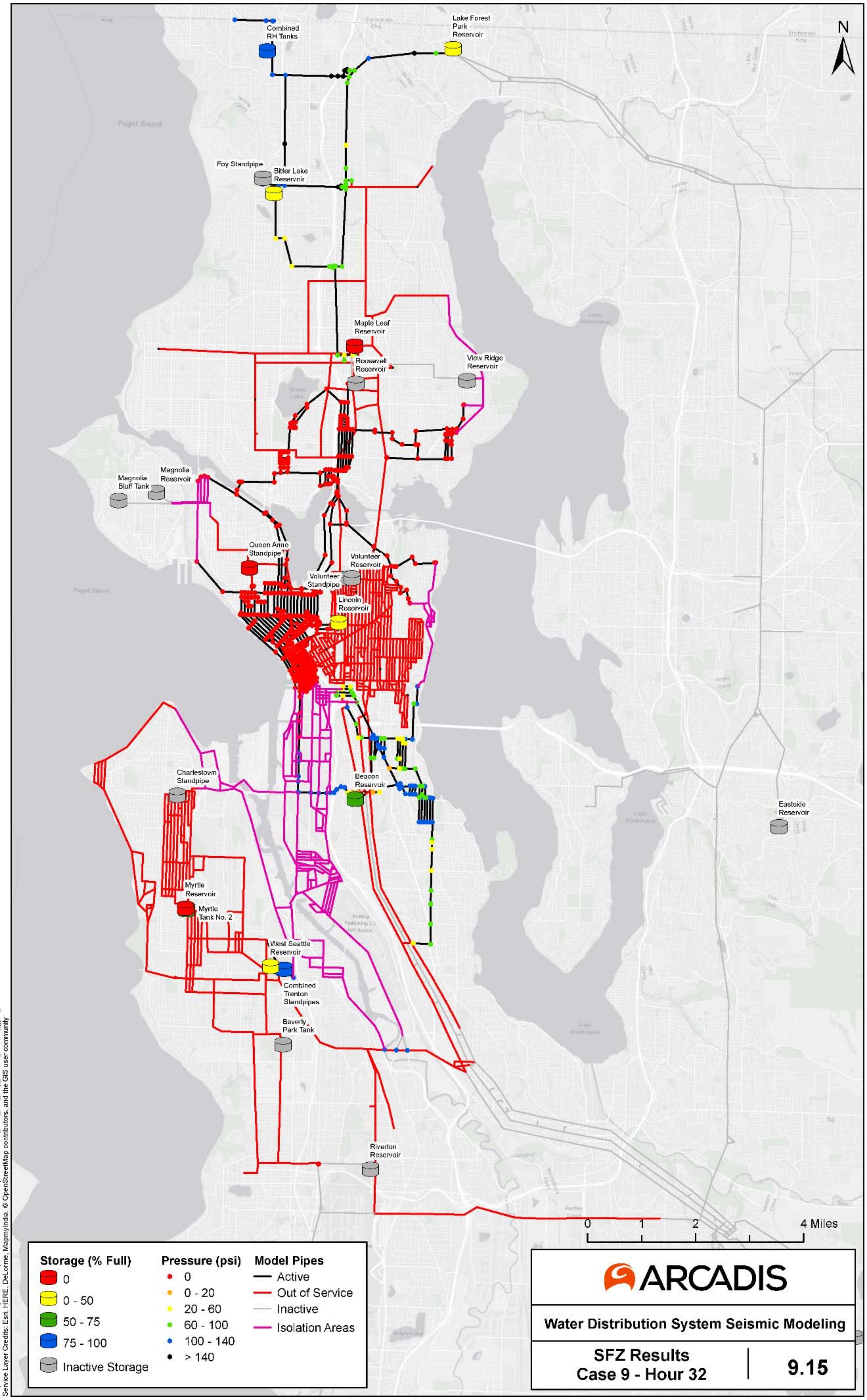
Out of Service
Inactive
Isolation Areas
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 9 - Hour 28
9.14



ARCADIS

Water Distribution System Seismic Modeling

SFZ Results
Case 9 - Hour 32

9.15

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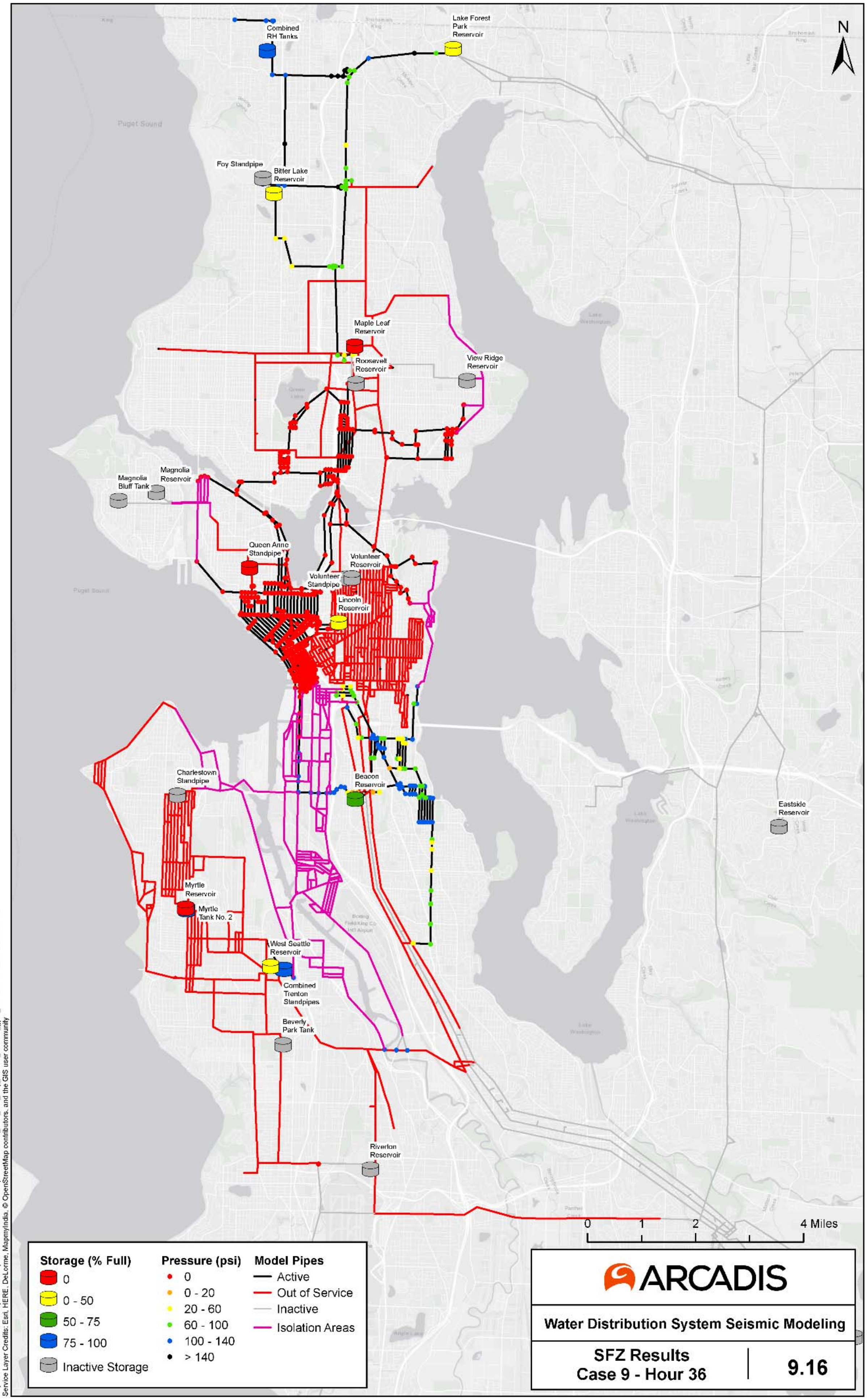

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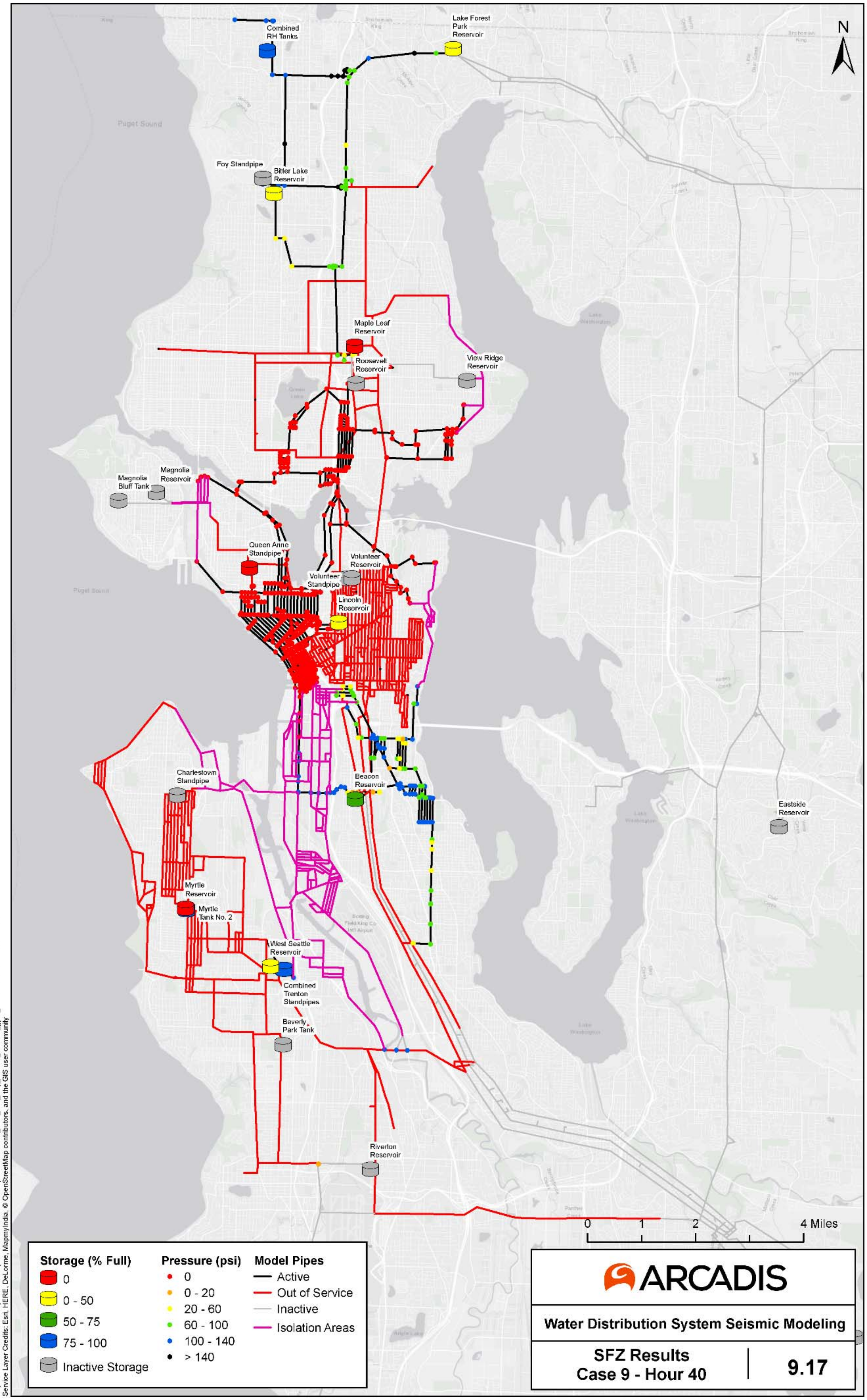

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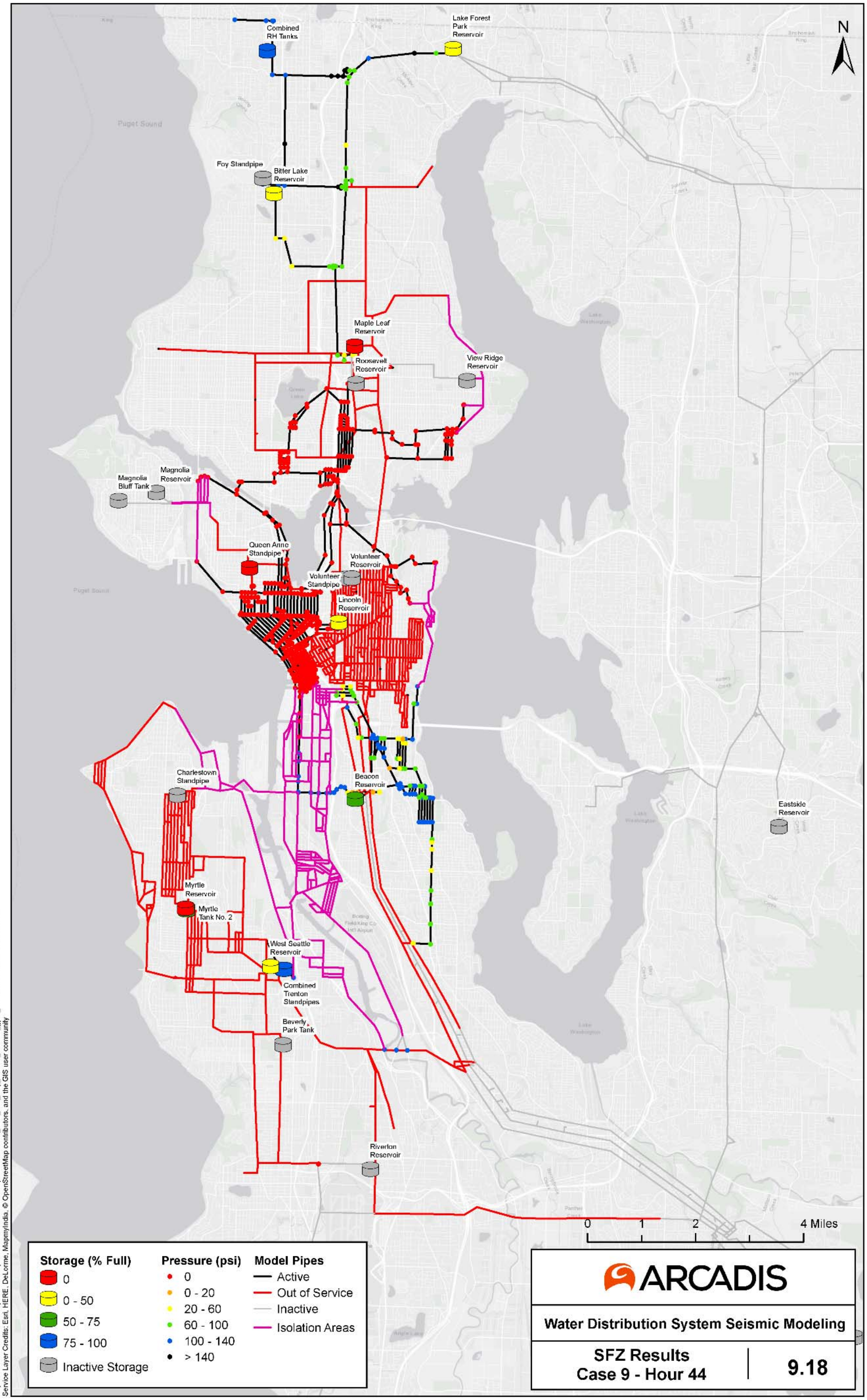

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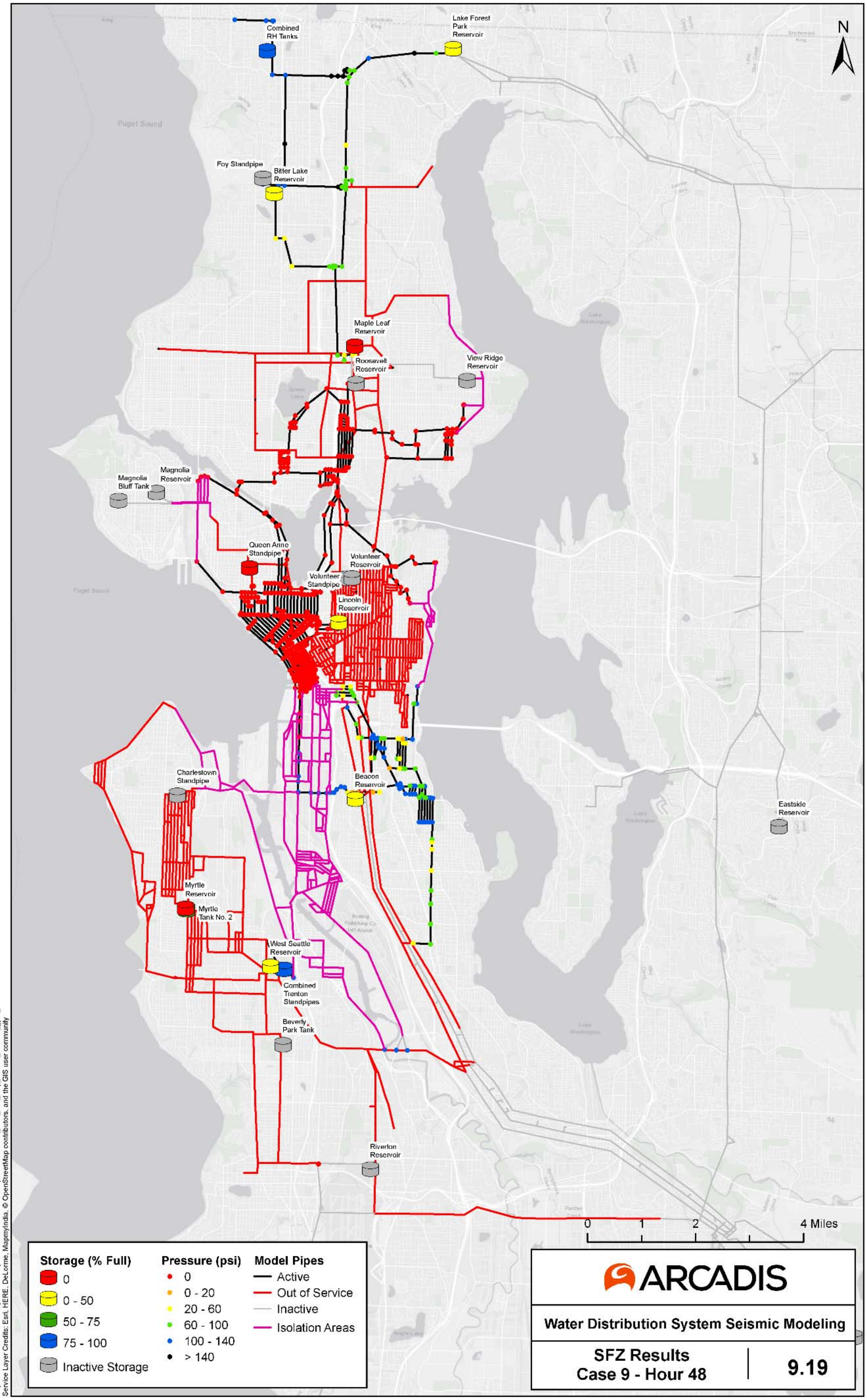

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M7.0 Seattle Fault Zone Case 10 (20 Year Improvements Plus One of the Cedar River Pipelines is Functional) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

2/6/2018

Seattle Fault Seismic Event

Case 10 Same as Case 1

CRPL #2 and West Seattle Pipelines are Functional

In Service Storage	*In Service Facilities*
Eastside Reservoir	Lincoln PS
Magnolia Bluff Elevated Tank	Broadway PS
Magnolia Reservoir	Spokane Street PS
Riverton Heights Reservoir	West Seattle PS

Model Results

Time (hrs)	Total System Demand (gpm)	Emiter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	149,870	121,579	28,291	87%	287.2
3	136,871	109,236	27,635	86%	268.3
12	123,522	96,801	26,721	82%	219.6
22	123,458	96,990	26,468	80%	166.3
32	82,052	63,604	18,447	52%	125.4
48	45,414	31,322	14,092	44%	90.7

Model Regions Forced Out of Service During Simulation

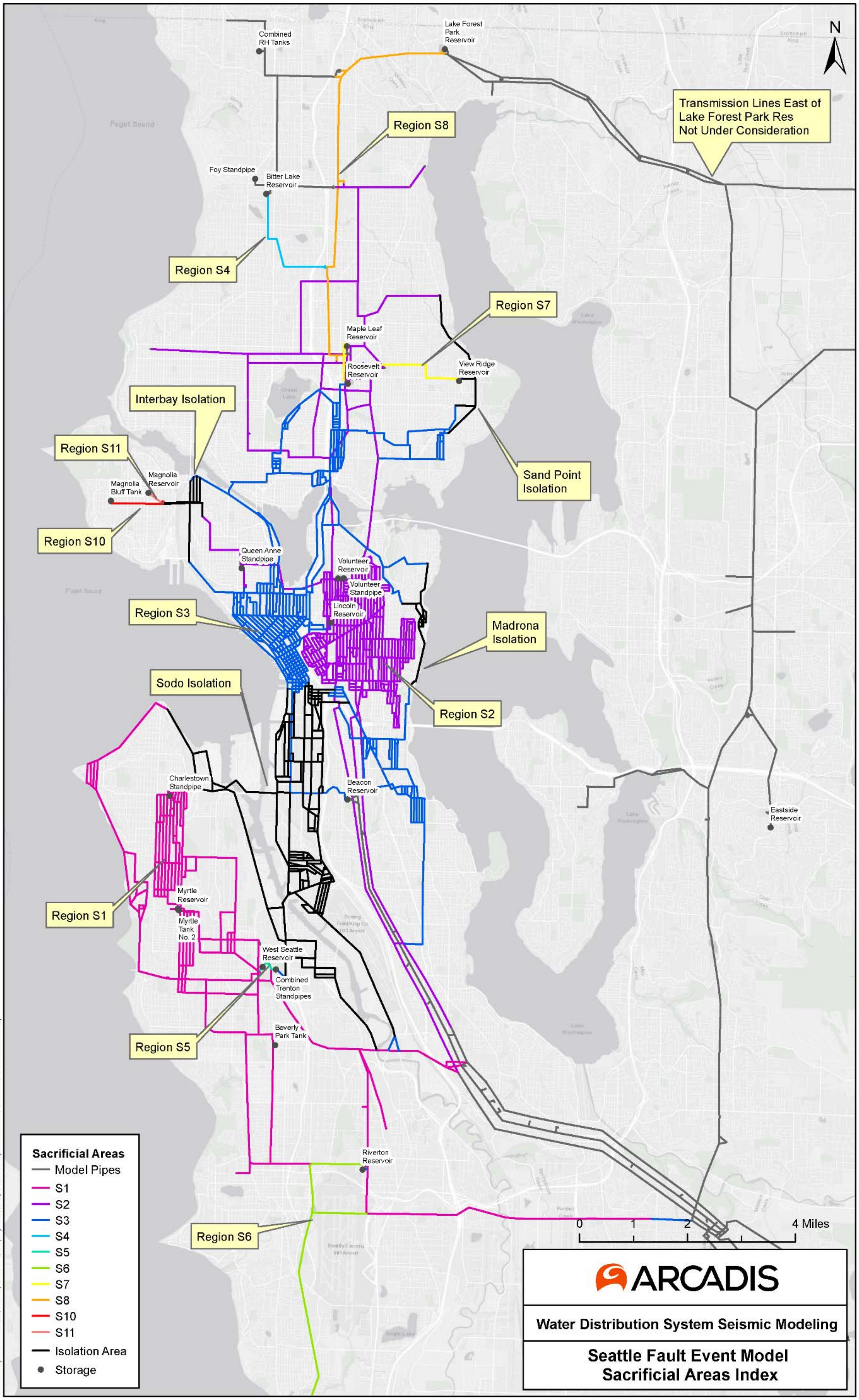
Time	Region
1	S10
29	S6
45	S4
45	S8

Model Simulation Notes

1. *Satisfied Demands assume junction pressure greater than 0 psi*
2. *System Positive Pressure based on number of junctions above 0 psi*
3. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
4. *Reported Demands & Positive Pressure ignores transmission mains East of Lake Forest Park Reservoir (Total Demand = 13,786 gpm)*

Model Results Figure Index

Fig. 10.1	Hr 0	Fig. 10.5	Hr 8	Fig. 10.9	Hr 16	Fig. 10.13	Hr 24	Fig. 10.17	Hr 40
Fig. 10.2	Hr 2	Fig. 10.6	Hr 10	Fig. 10.10	Hr 18	Fig. 10.14	Hr 28	Fig. 10.18	Hr 44
Fig. 10.3	Hr 4	Fig. 10.7	Hr 12	Fig. 10.11	Hr 20	Fig. 10.15	Hr 32	Fig. 10.19	Hr 48
Fig. 10.4	Hr 6	Fig. 10.8	Hr 14	Fig. 10.12	Hr 22	Fig. 10.16	Hr 36		



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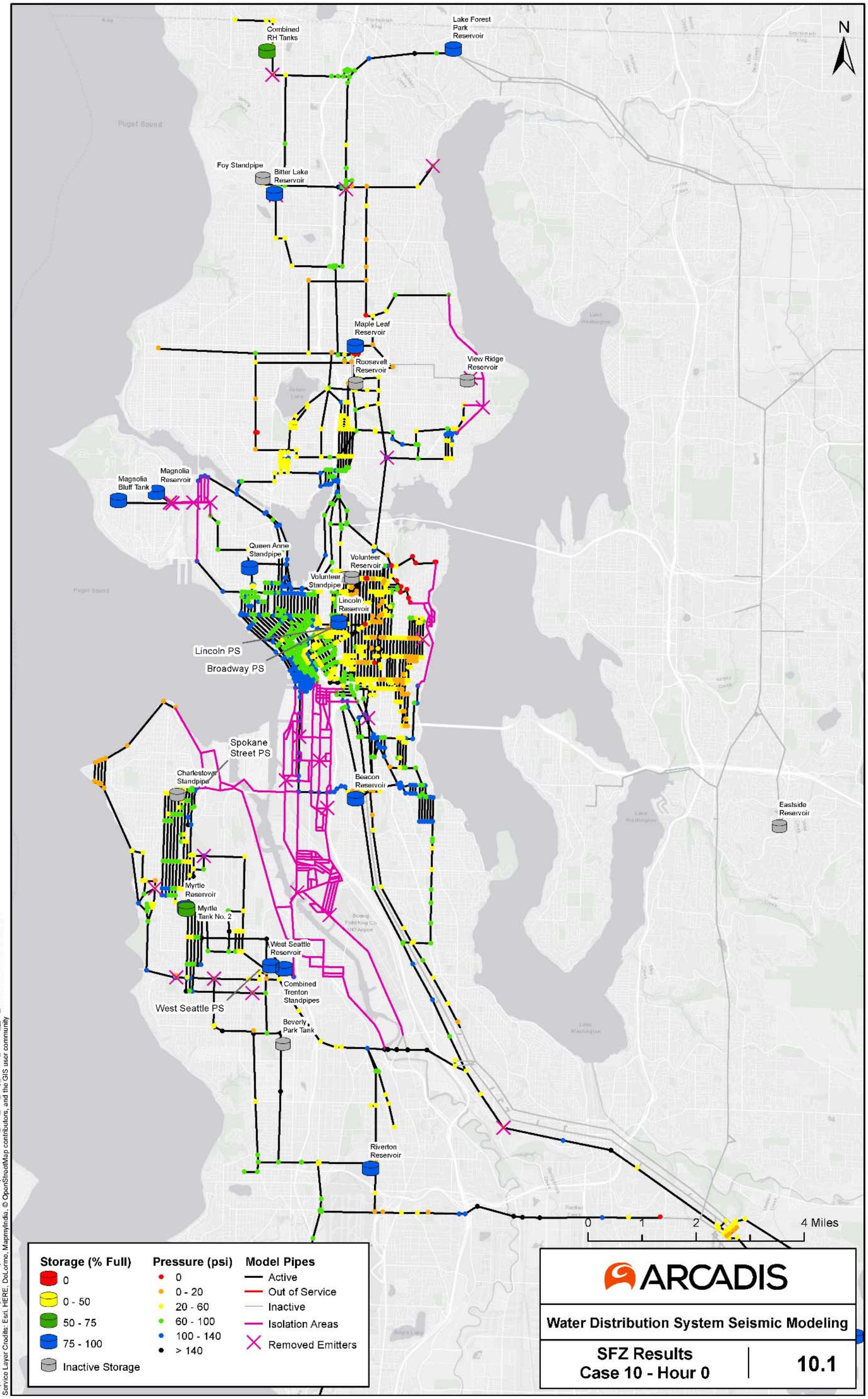

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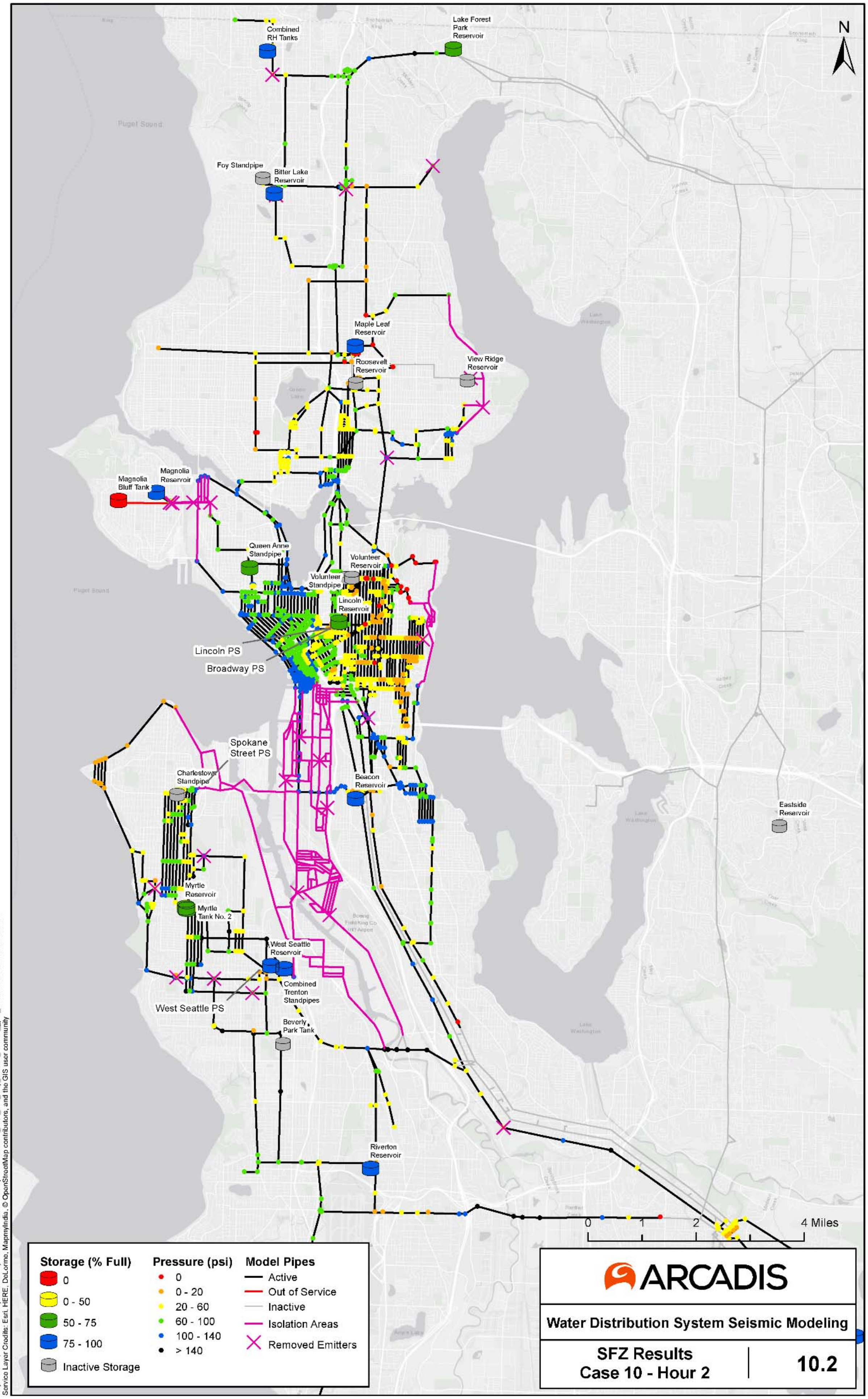

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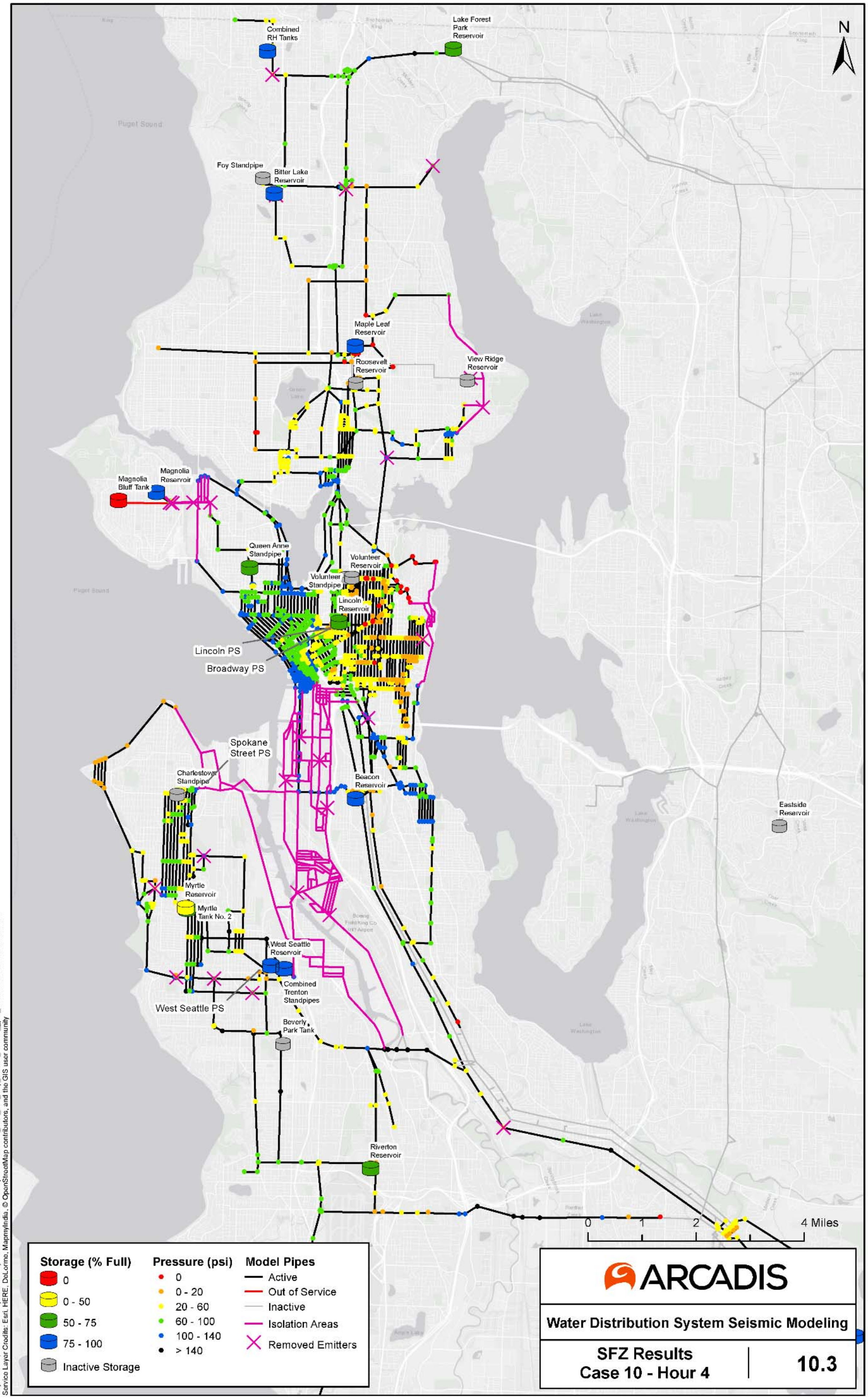

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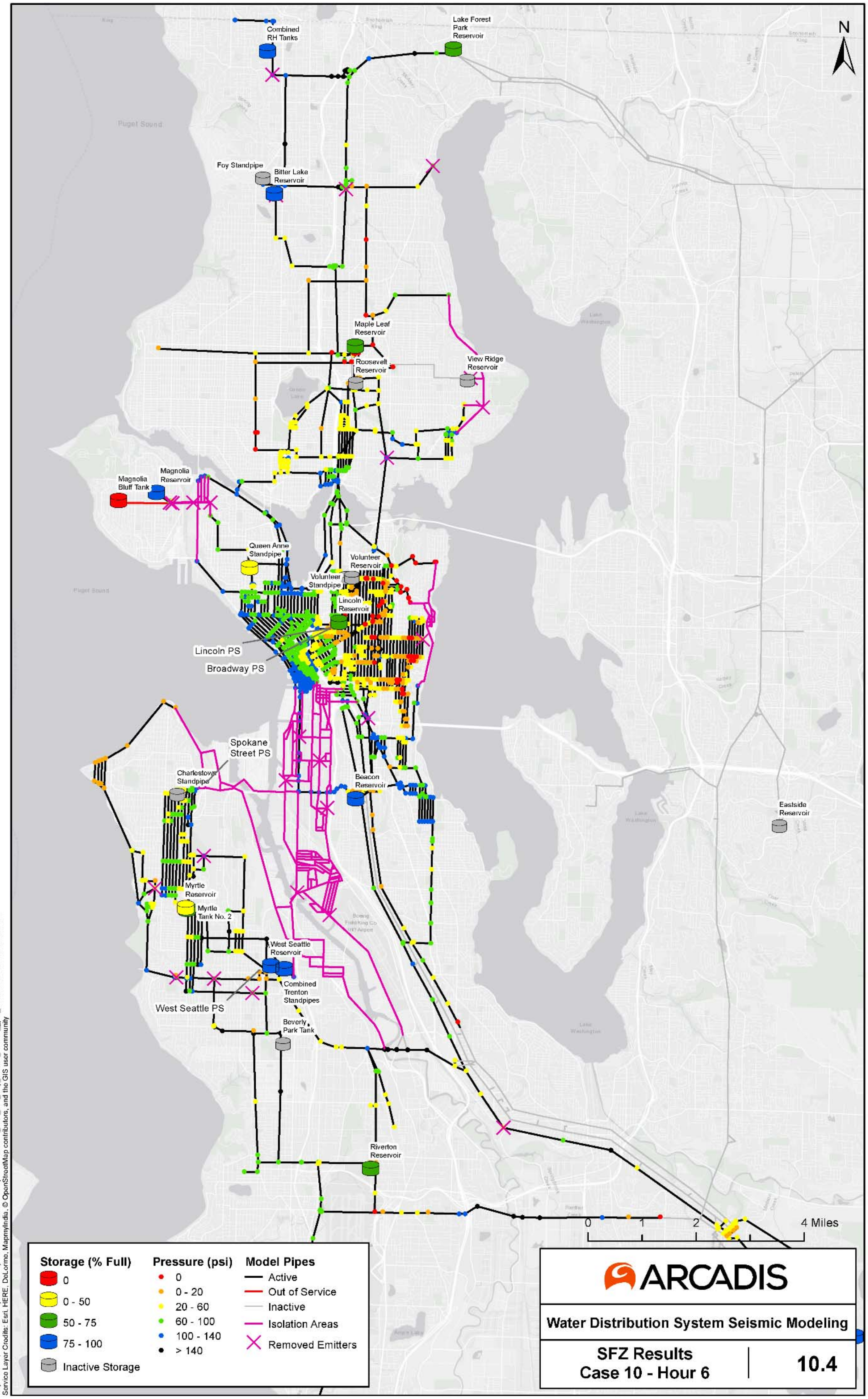

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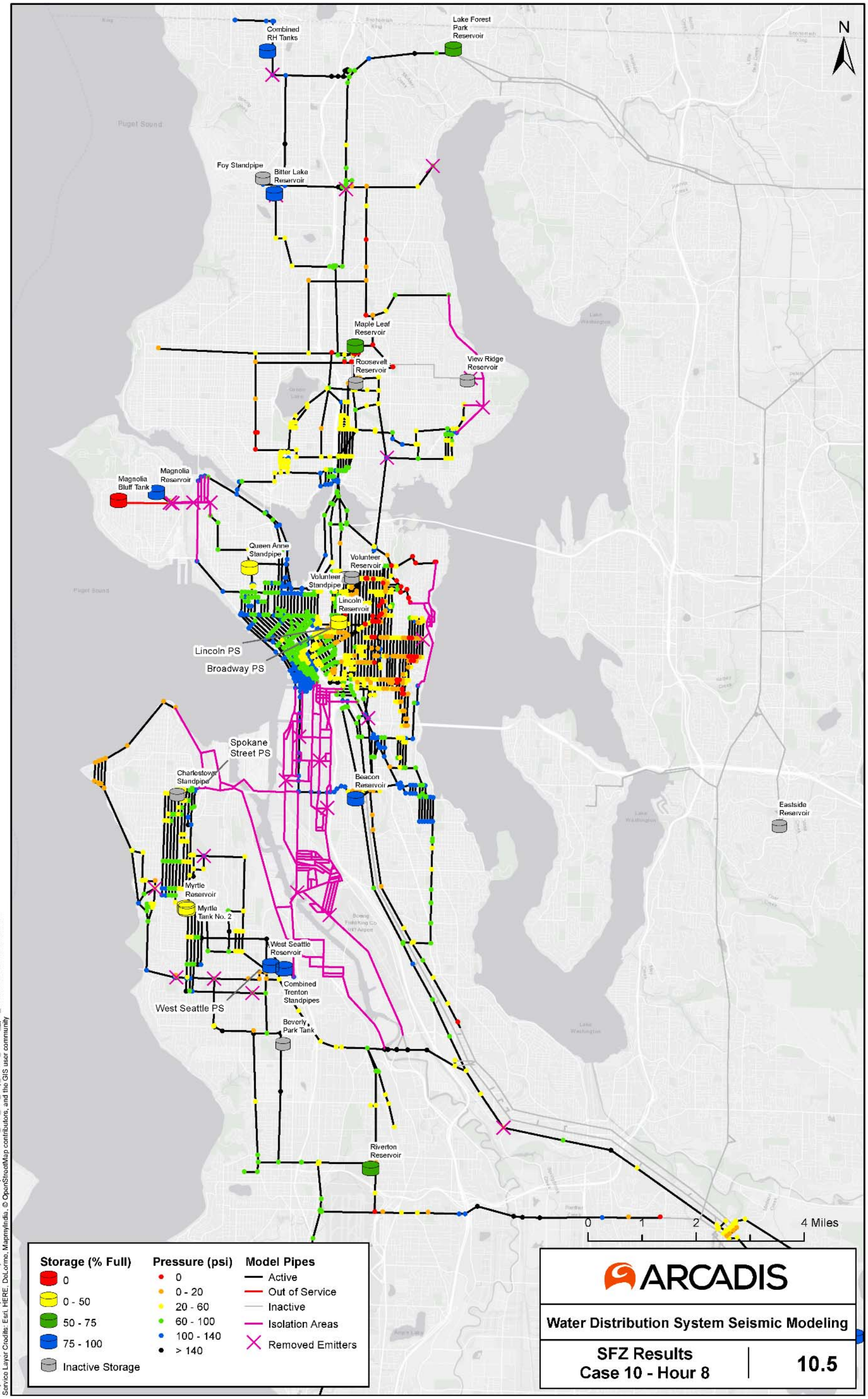

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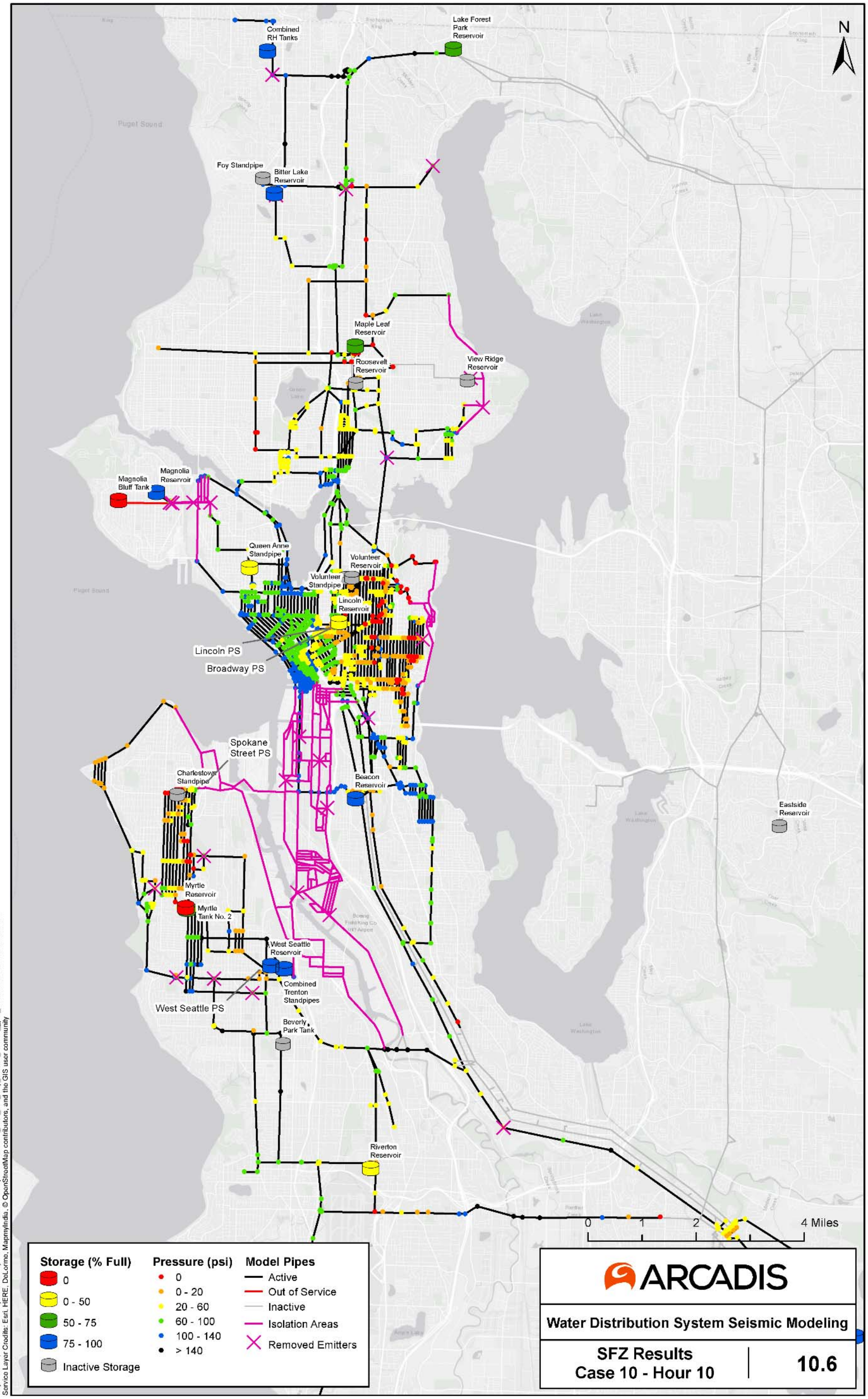

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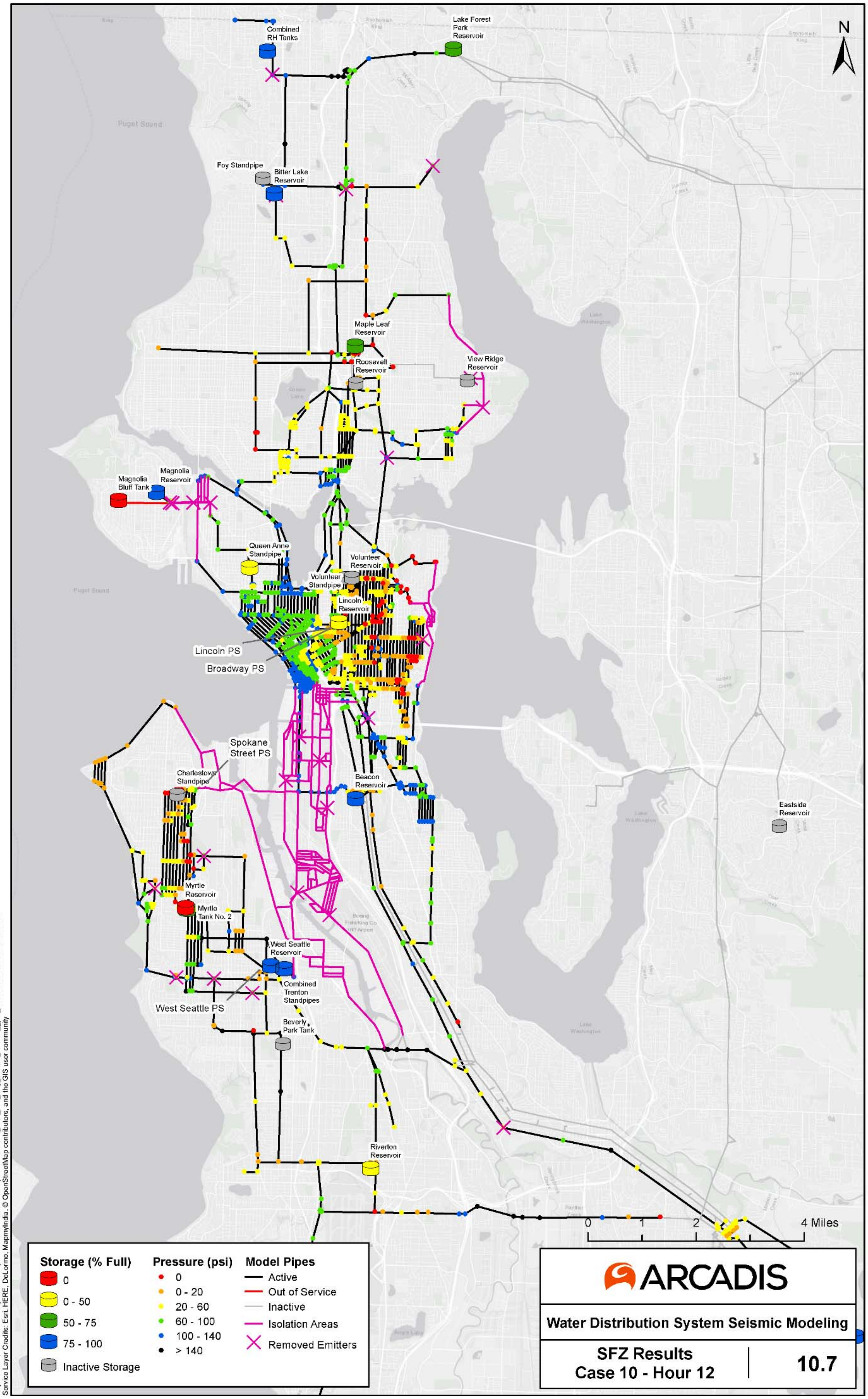

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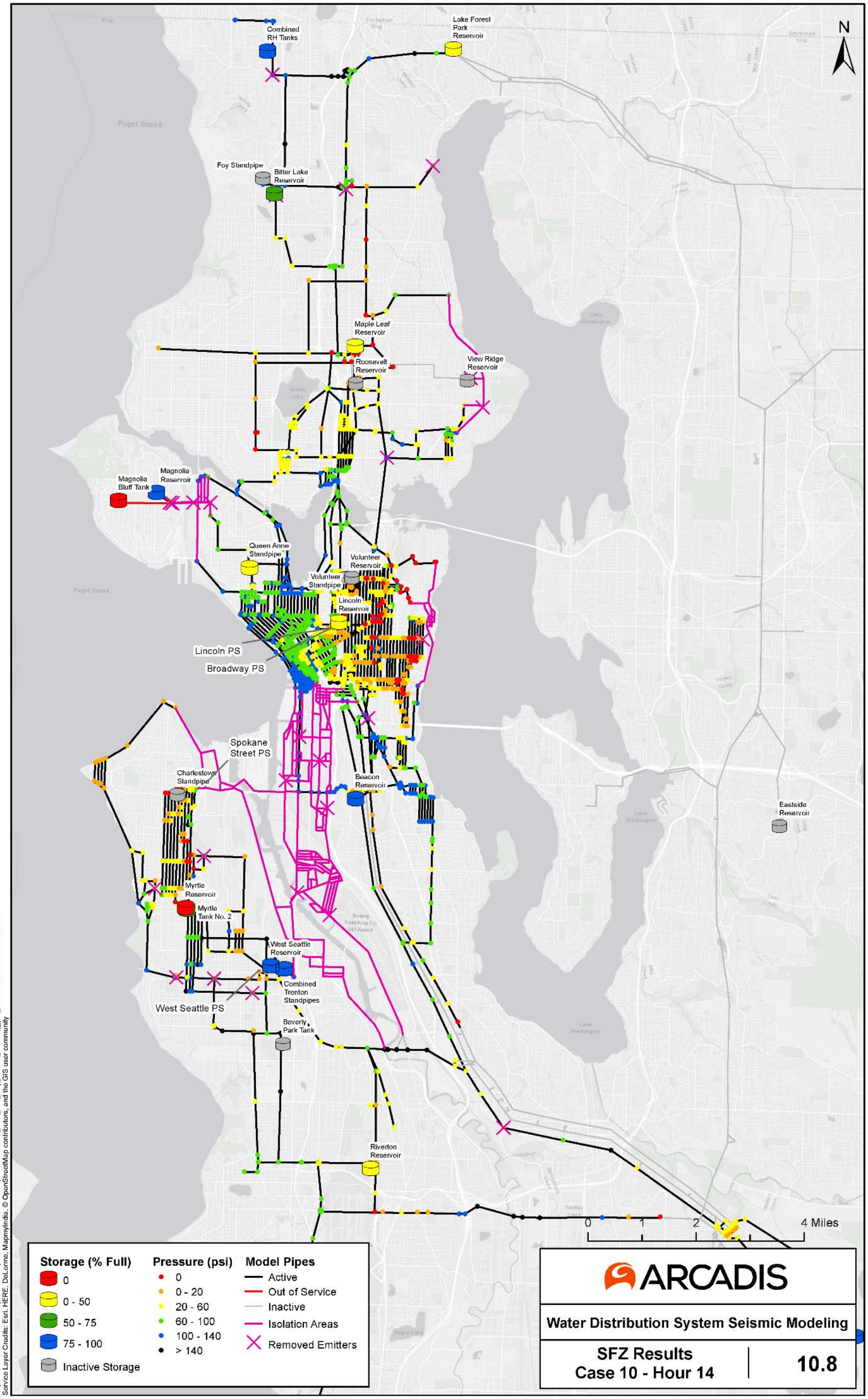

Combined RH Tanks
Lake Forest Park Reservoir
N
Puget Sound
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
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Magnolia Bluff Tank
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1
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4 Miles
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Inactive Storage
Pressure (psi)
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> 140
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Inactive
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Removed Emitters
ARCADIS
Water Distribution System Seismic Modeling
SFZ Results
Case 10 - Hour 14
10.8
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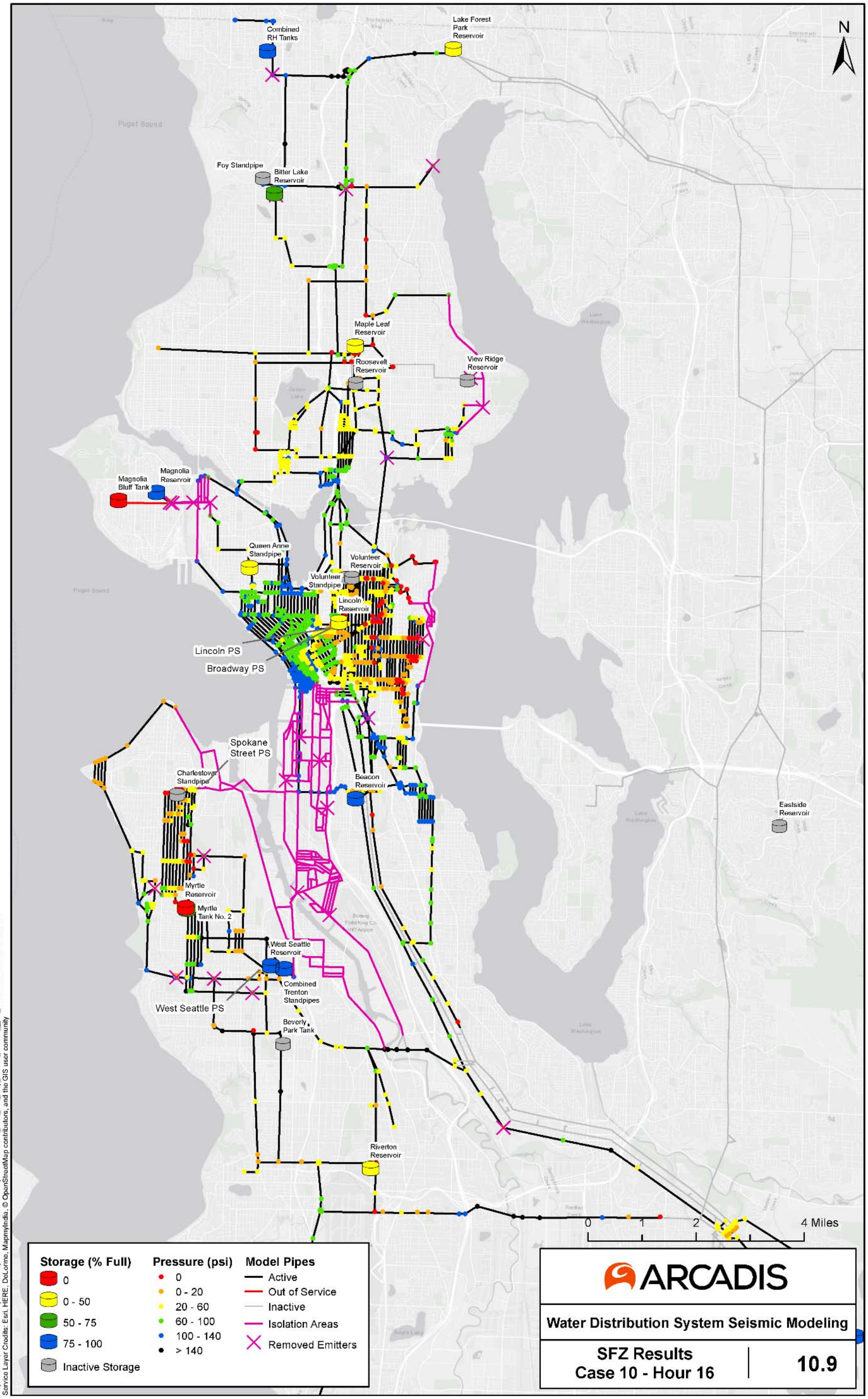

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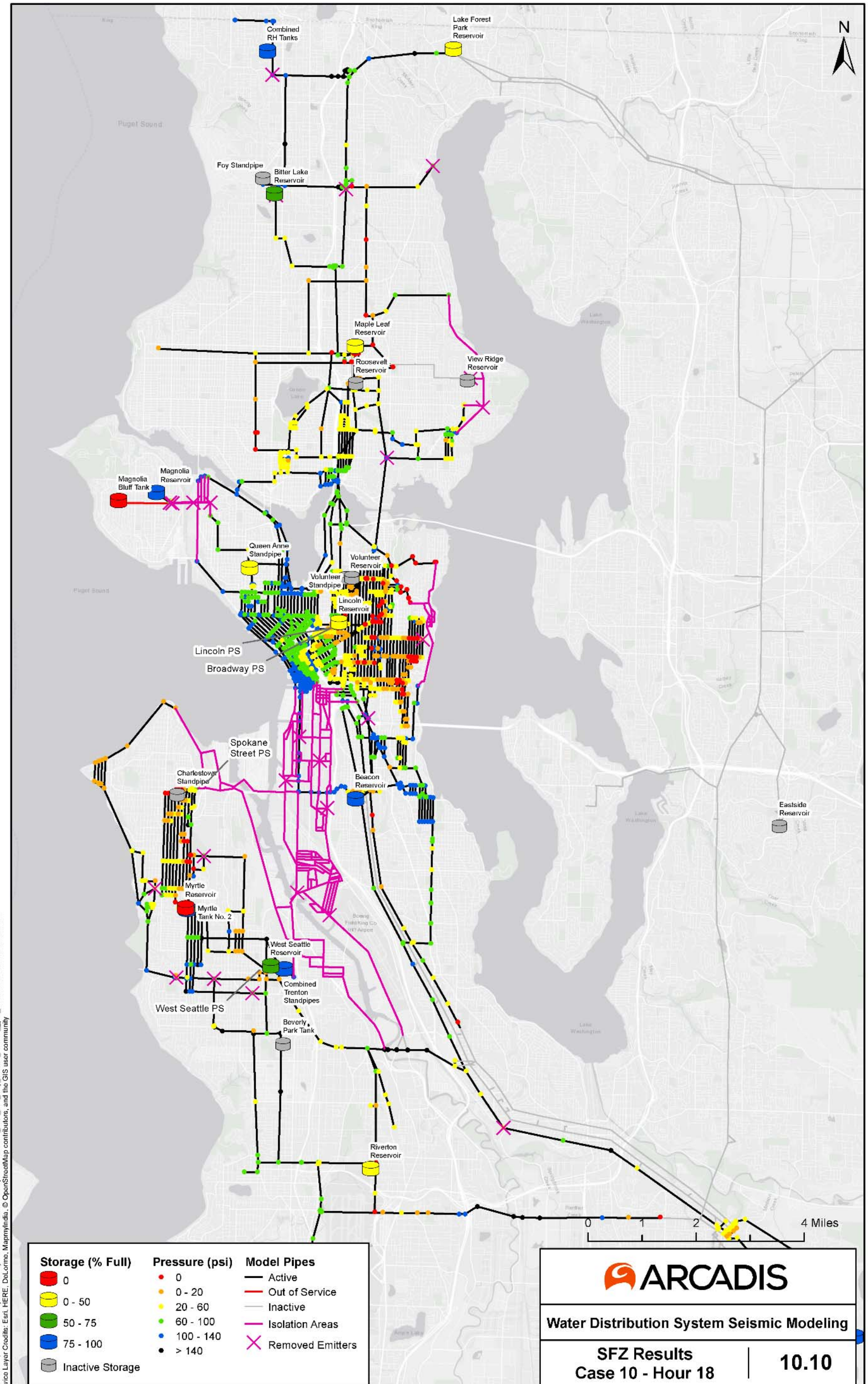

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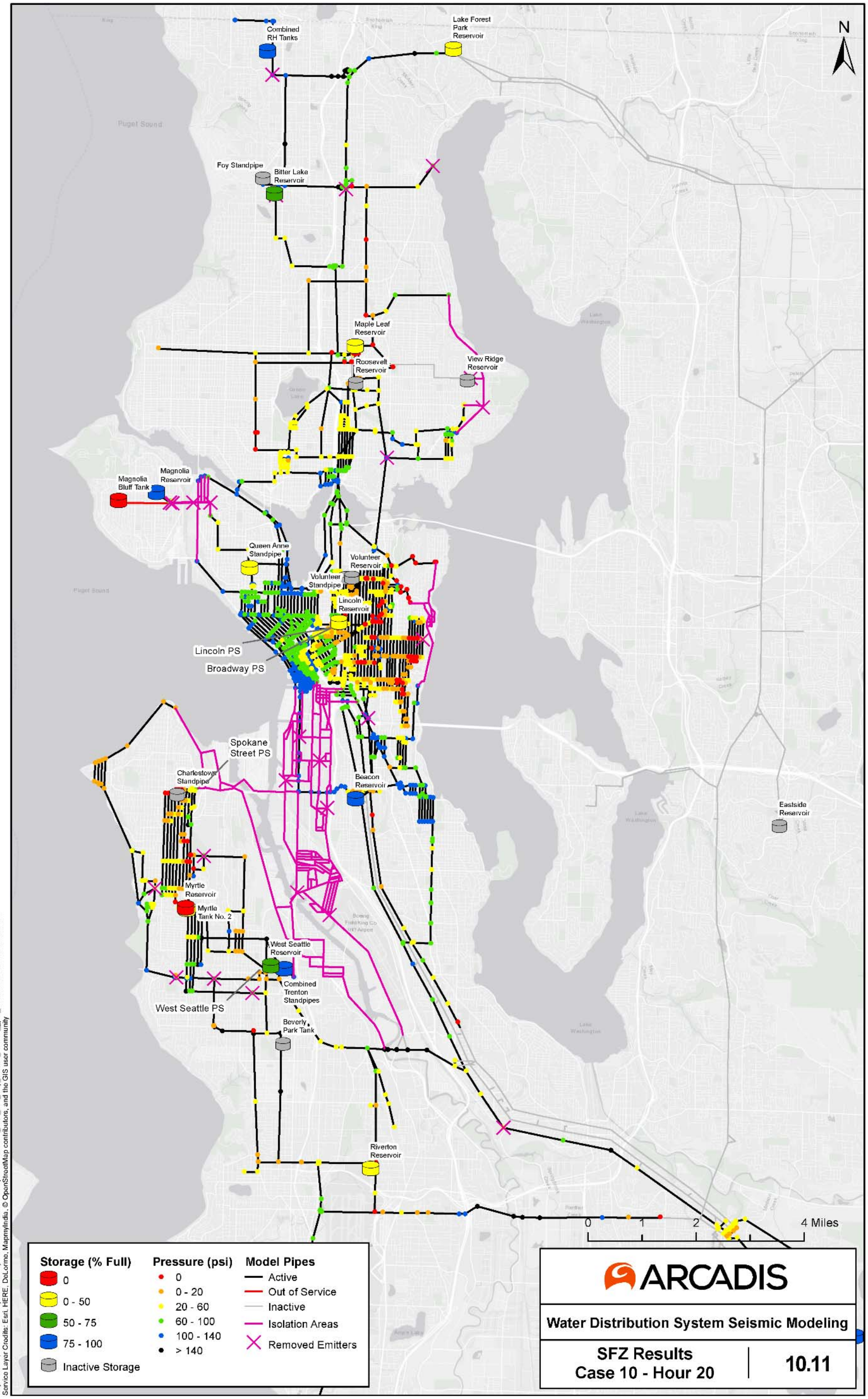

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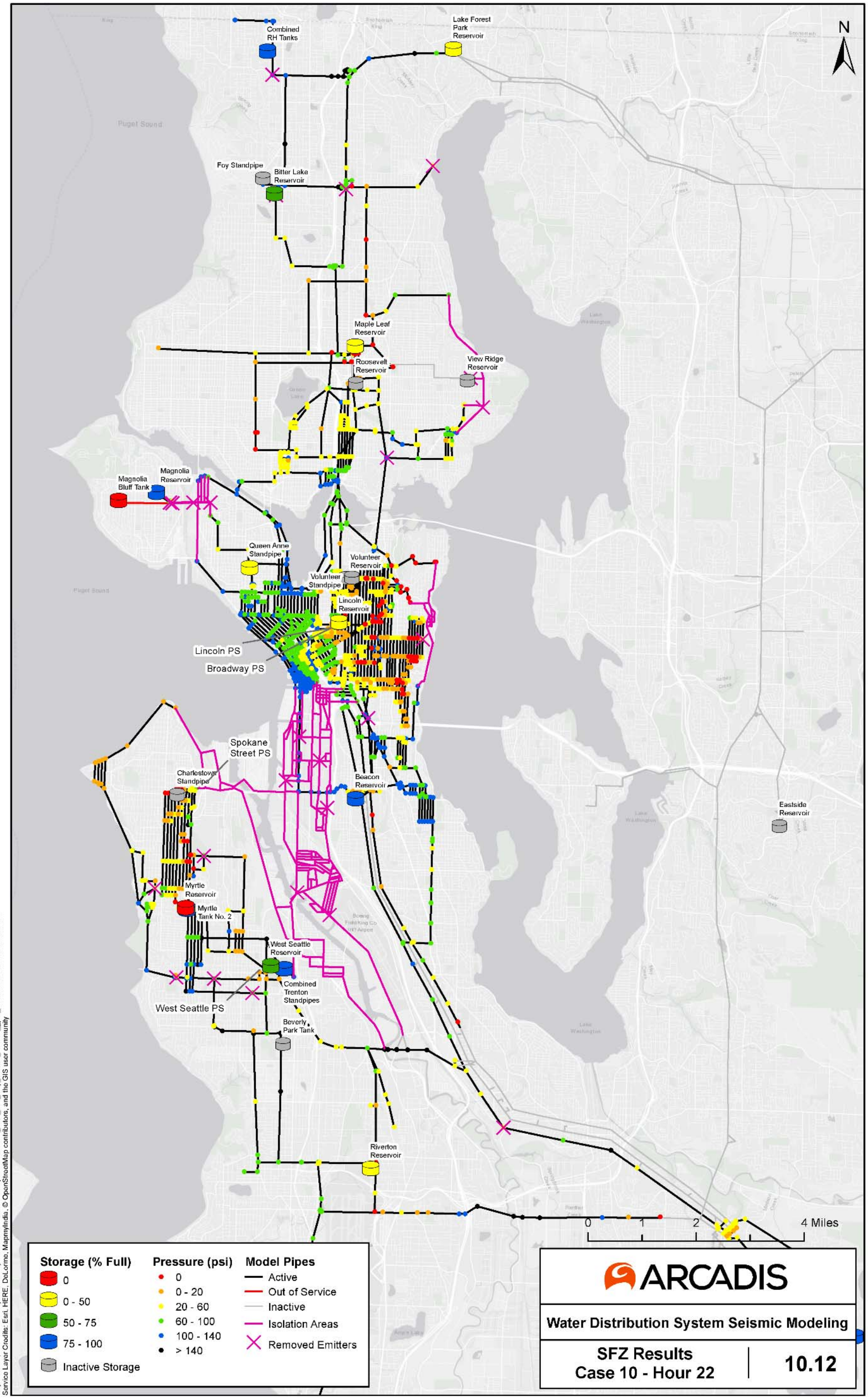

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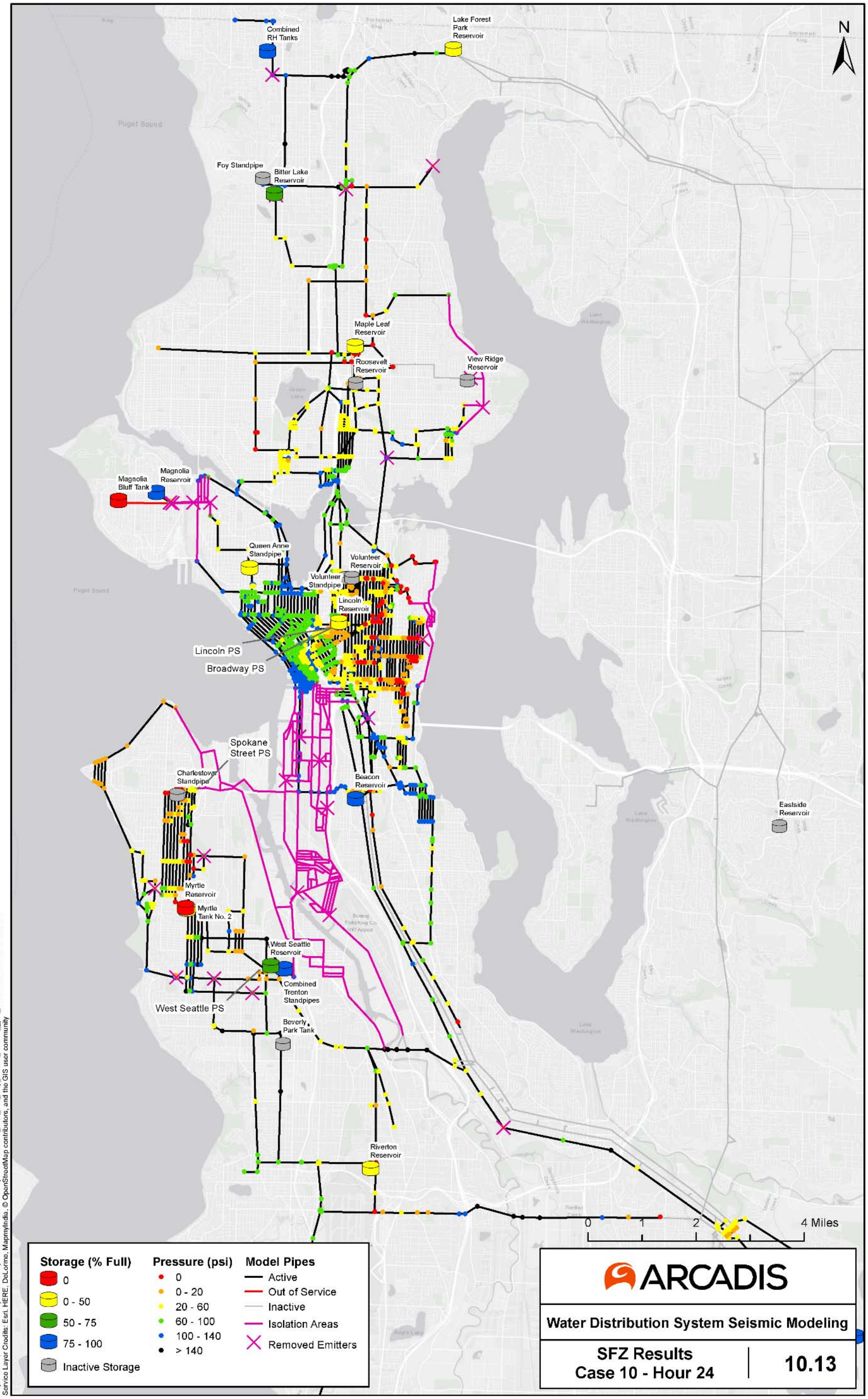

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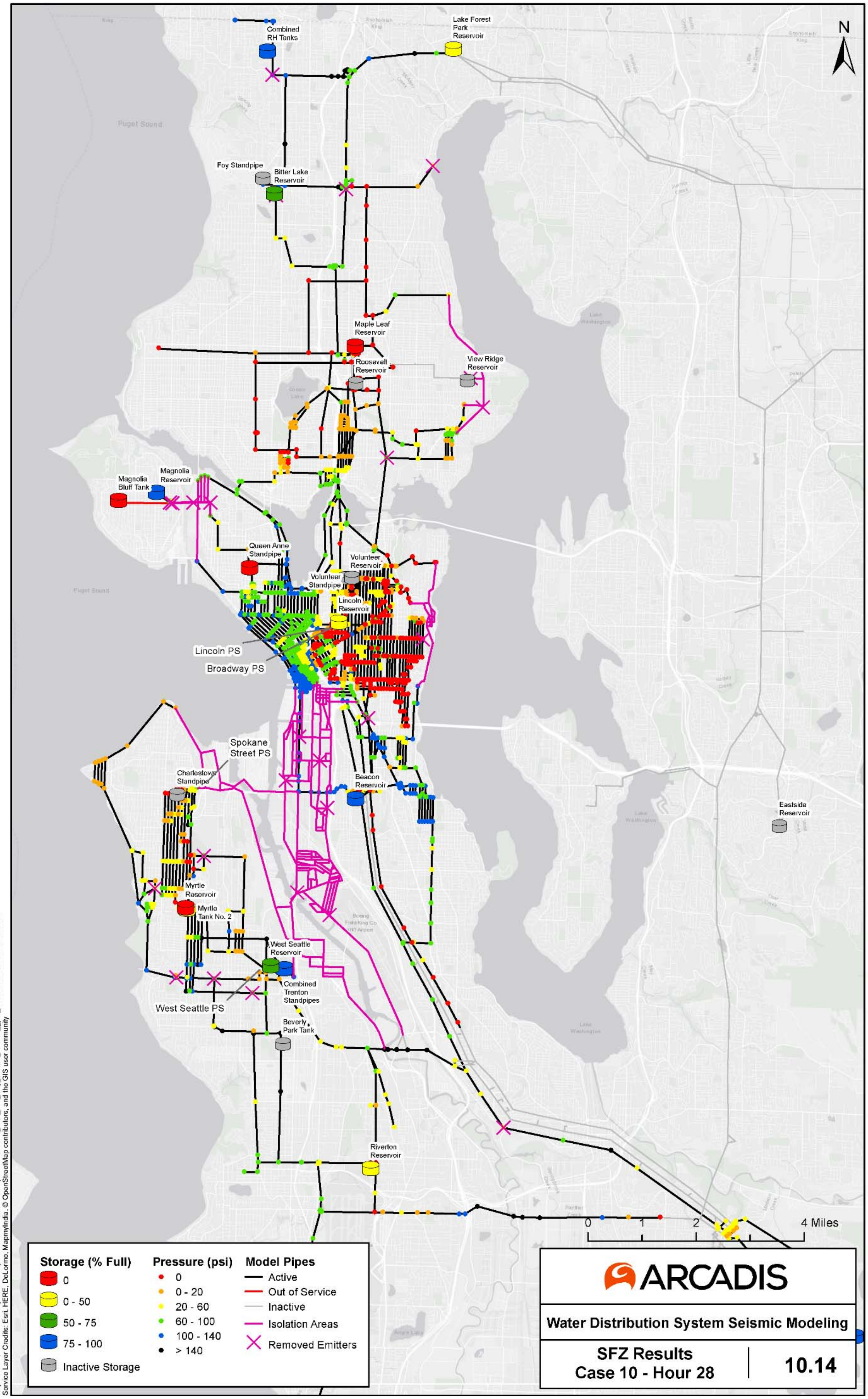

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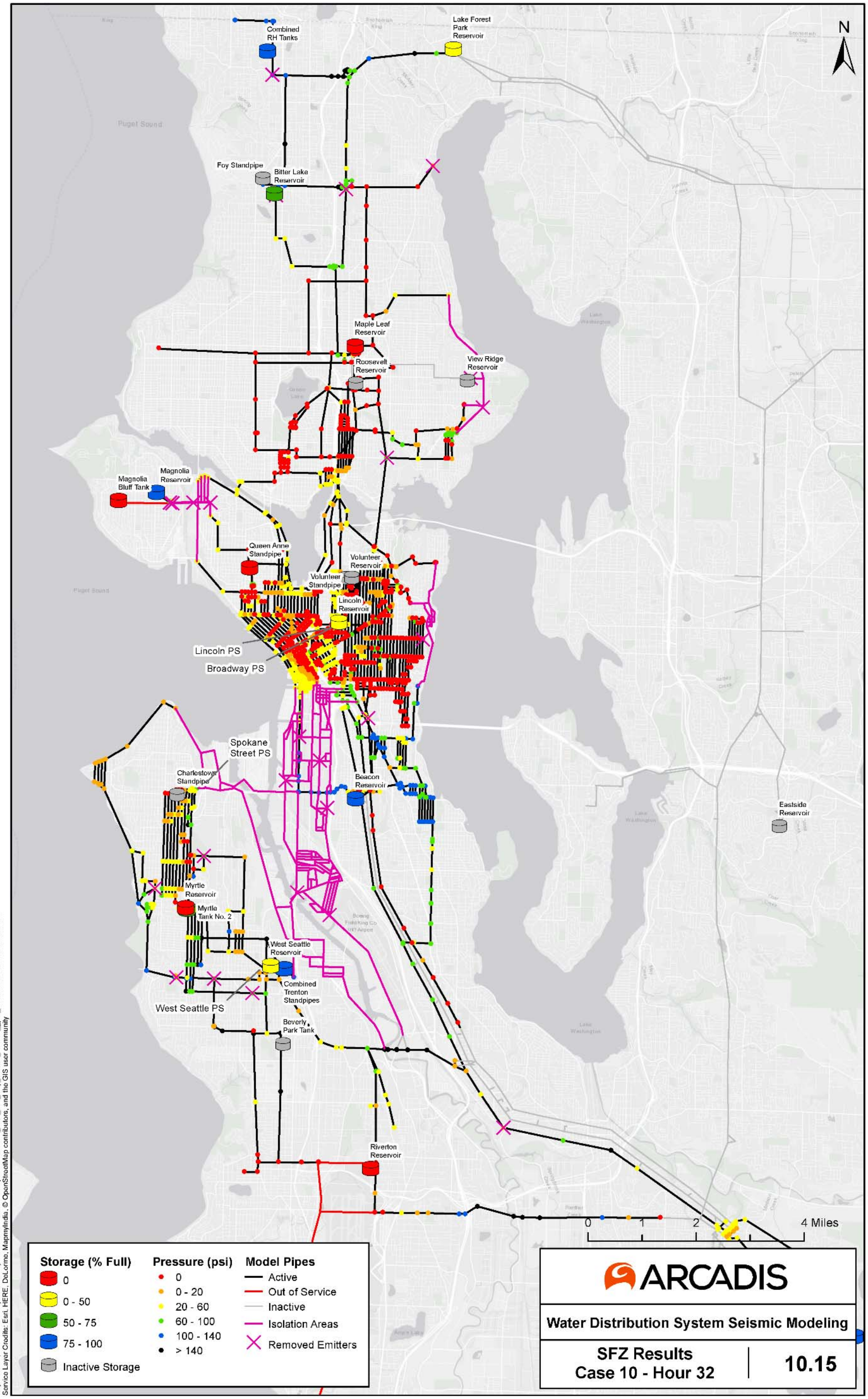

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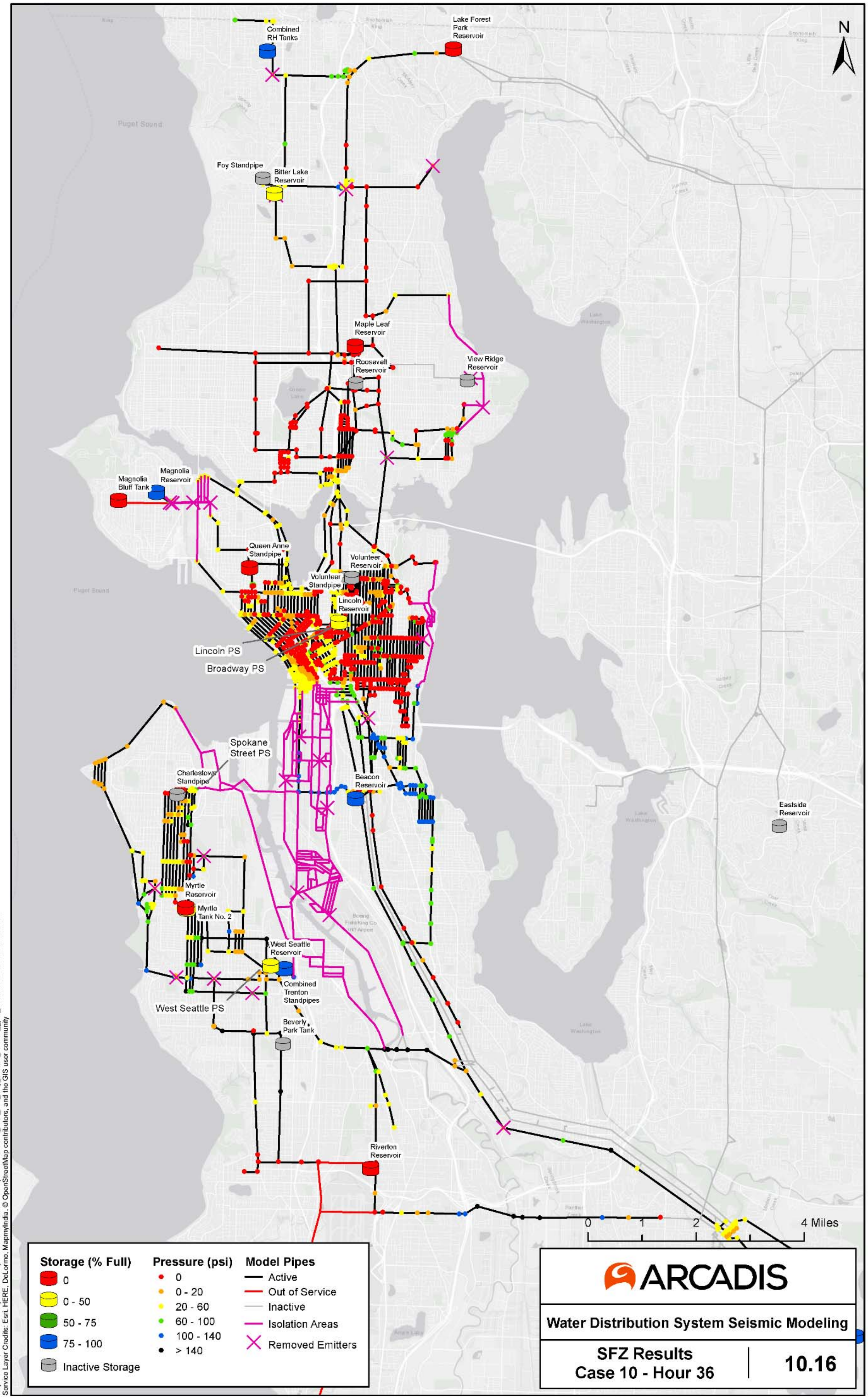

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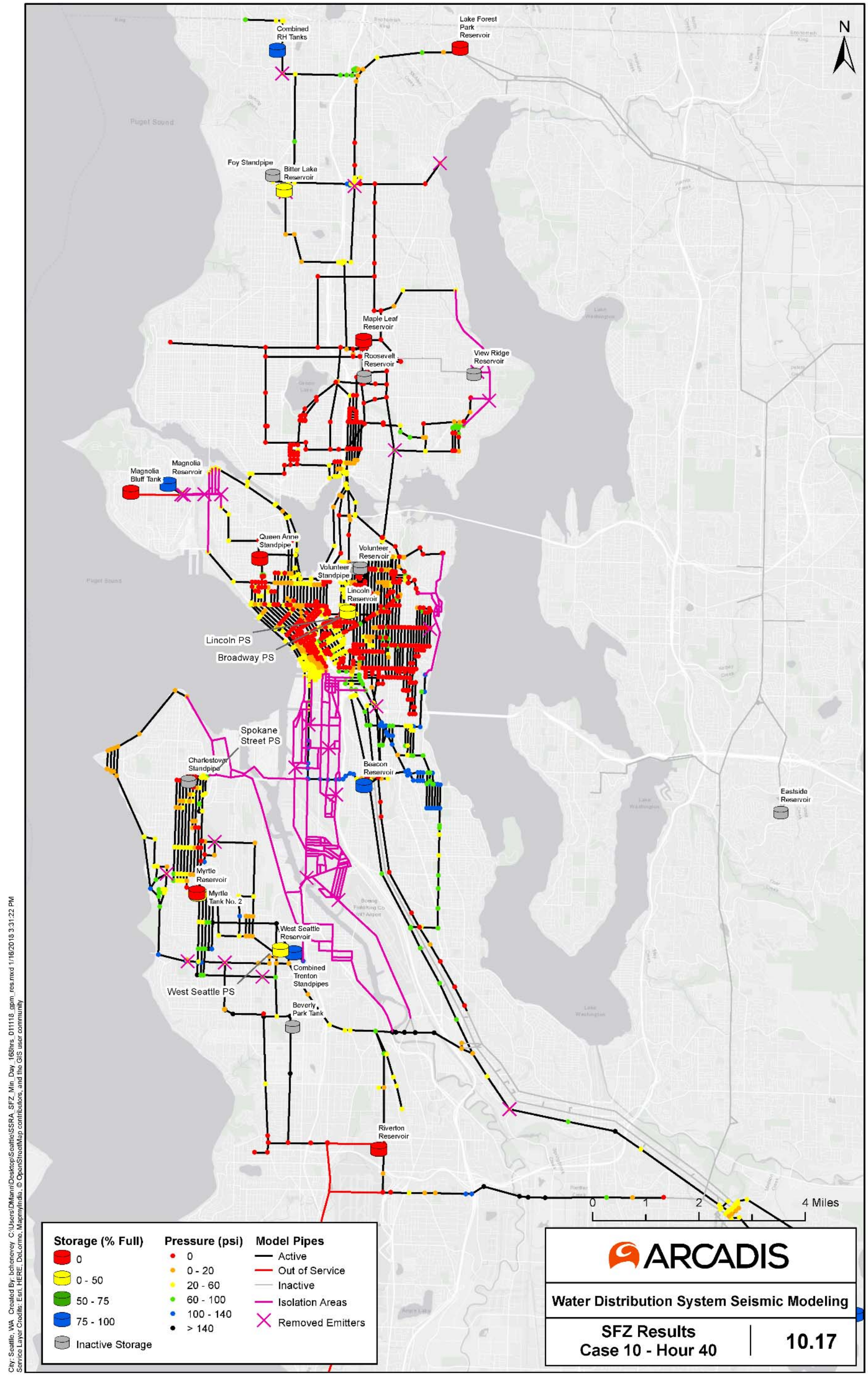

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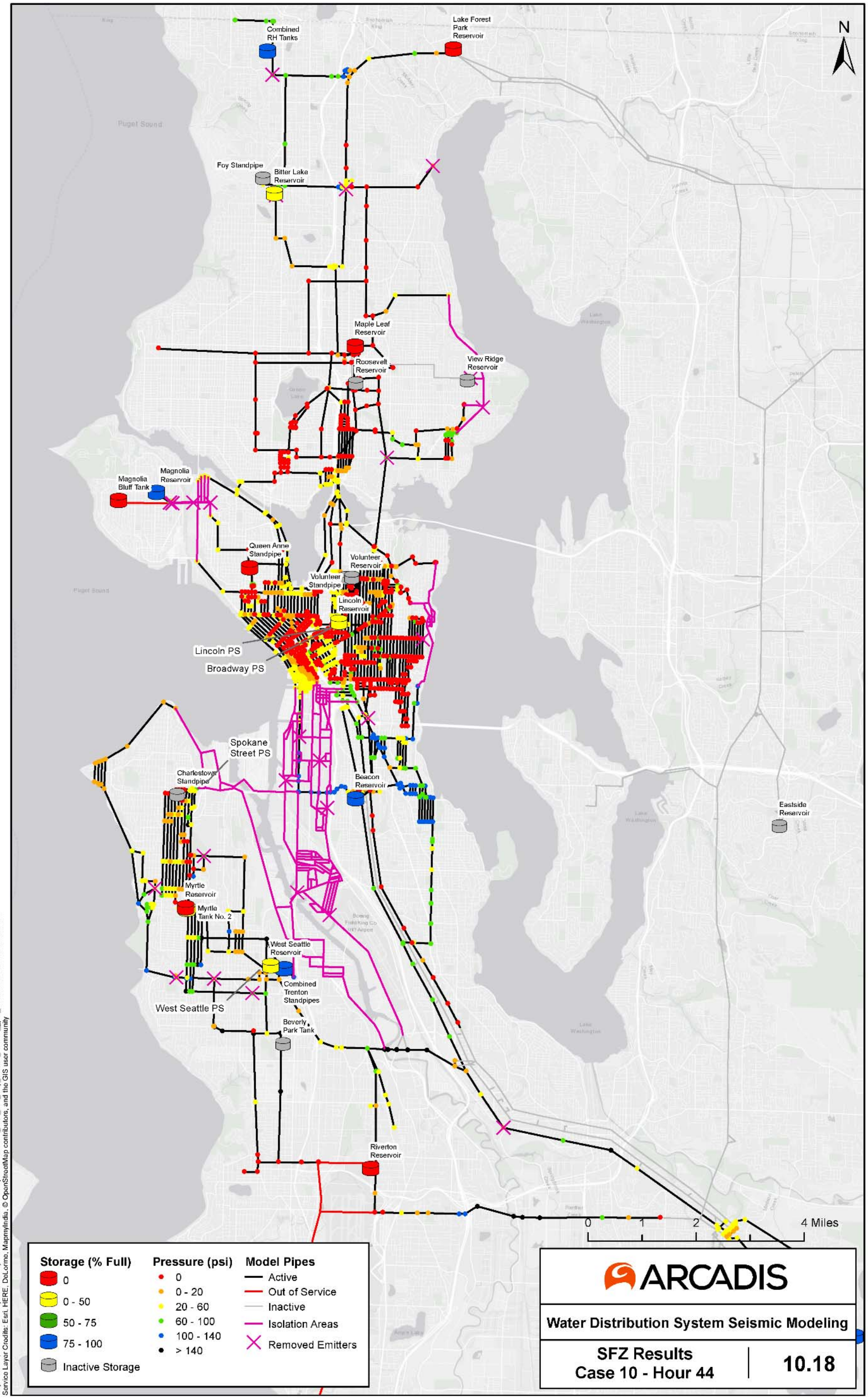

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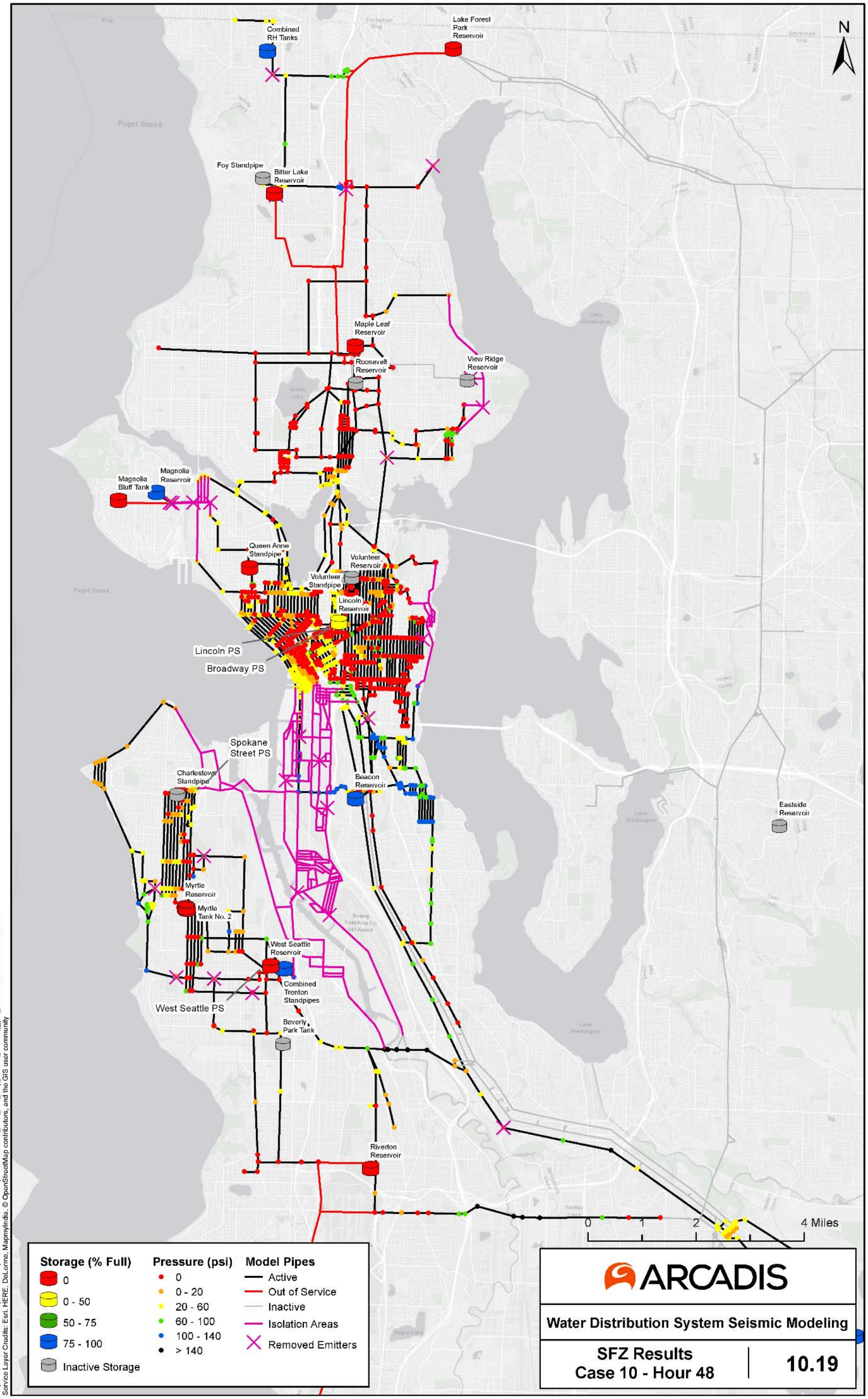

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M7.0 Seattle Fault Zone Transmission Pipeline Base Case (No Improvements) Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

4/3/2018

Seattle Fault Seismic Event
Transmission Pipeline Simulations

Base 2018

Water from Tolt Filtration Plant cannot be conveyed west

Water from Control Works (Cedar System) cannot be conveyed into the distibution system

Other assumptions are the same as the Base SFZ scenario

Model Results

Time (hrs)	Total System Demand (gpm)	Emitter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	257,089	226,005	31,084	64%	244.3
3	239,604	214,223	25,381	57%	196.5
12	184,673	162,975	21,697	42%	85.1
22	31,108	23,889	7,219	6%	29.5
32	28,321	21,837	6,485	5%	14.4
48	6,485	0	6,485	5%	11.5

Model Regions Forced Out of Service During Simulation

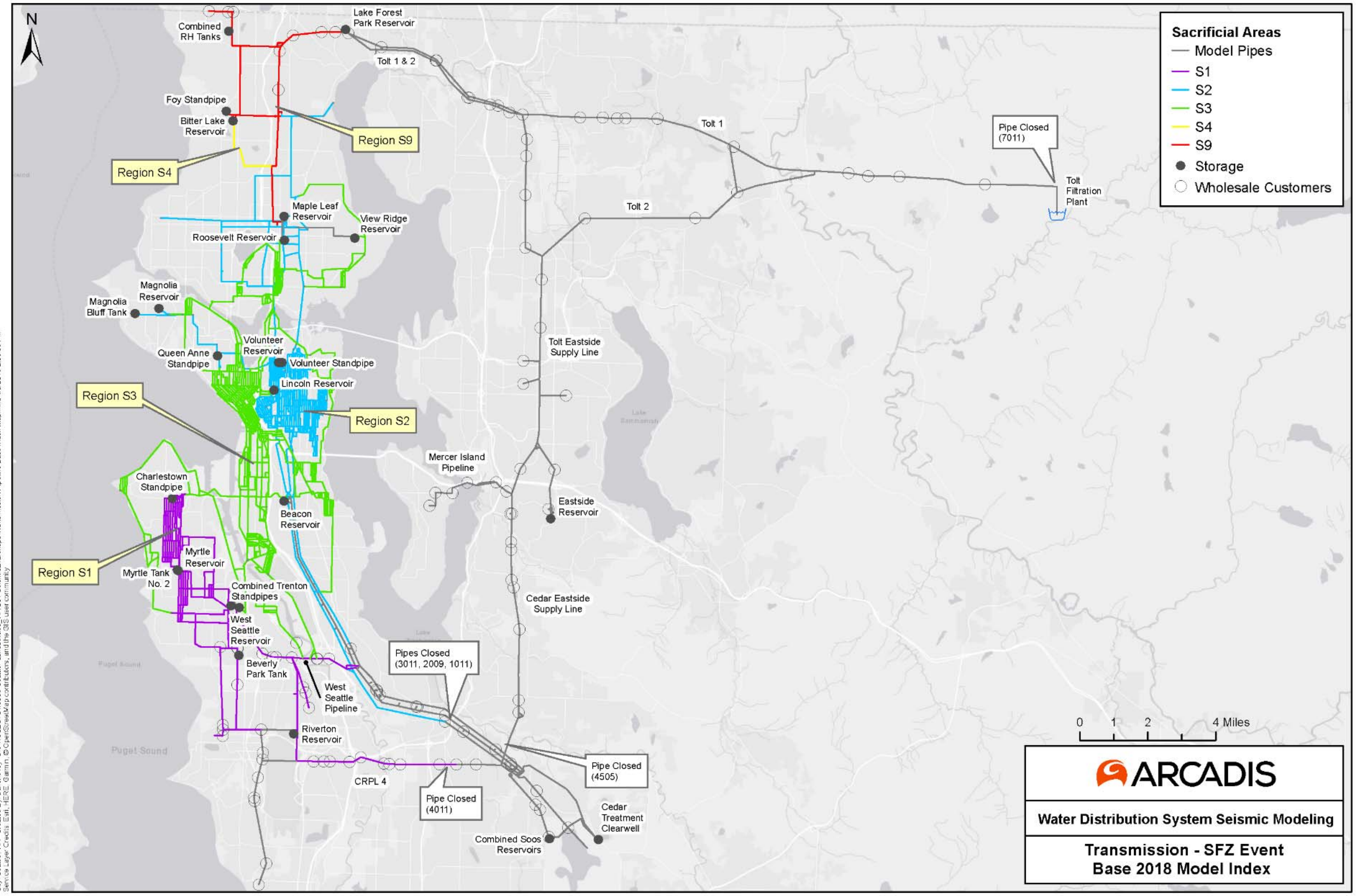
Time	Region
3	S1
15	S2
21	S3
21	S8
32	S4

Model Simulation Notes

1. *All wholesale customers assumed to start with 1.8 multiplier (max day demands)*
2. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
3. *Total Model Demands with elevated wholesale customers is 91,957 gpm*
4. *Satisfied Demands assume junction pressure greater than 0 psi*
5. *System Positive Pressure based on number of junctions above 0 psi out of* the entire model

Model Results Figure Index

Fig. 11.1	Hr 0	Fig. 11.5	Hr 8	Fig. 11.9	Hr 16	Fig. 11.13	Hr 24	Fig. 11.17	Hr 40
Fig. 11.2	Hr 2	Fig. 11.6	Hr 10	Fig. 11.10	Hr 18	Fig. 11.14	Hr 28	Fig. 11.18	Hr 44
Fig. 11.3	Hr 4	Fig. 11.7	Hr 12	Fig. 11.11	Hr 20	Fig. 11.15	Hr 32	Fig. 11.19	Hr 48
Fig. 11.4	Hr 6	Fig. 11.8	Hr 14	Fig. 11.12	Hr 22	Fig. 11.16	Hr 36		



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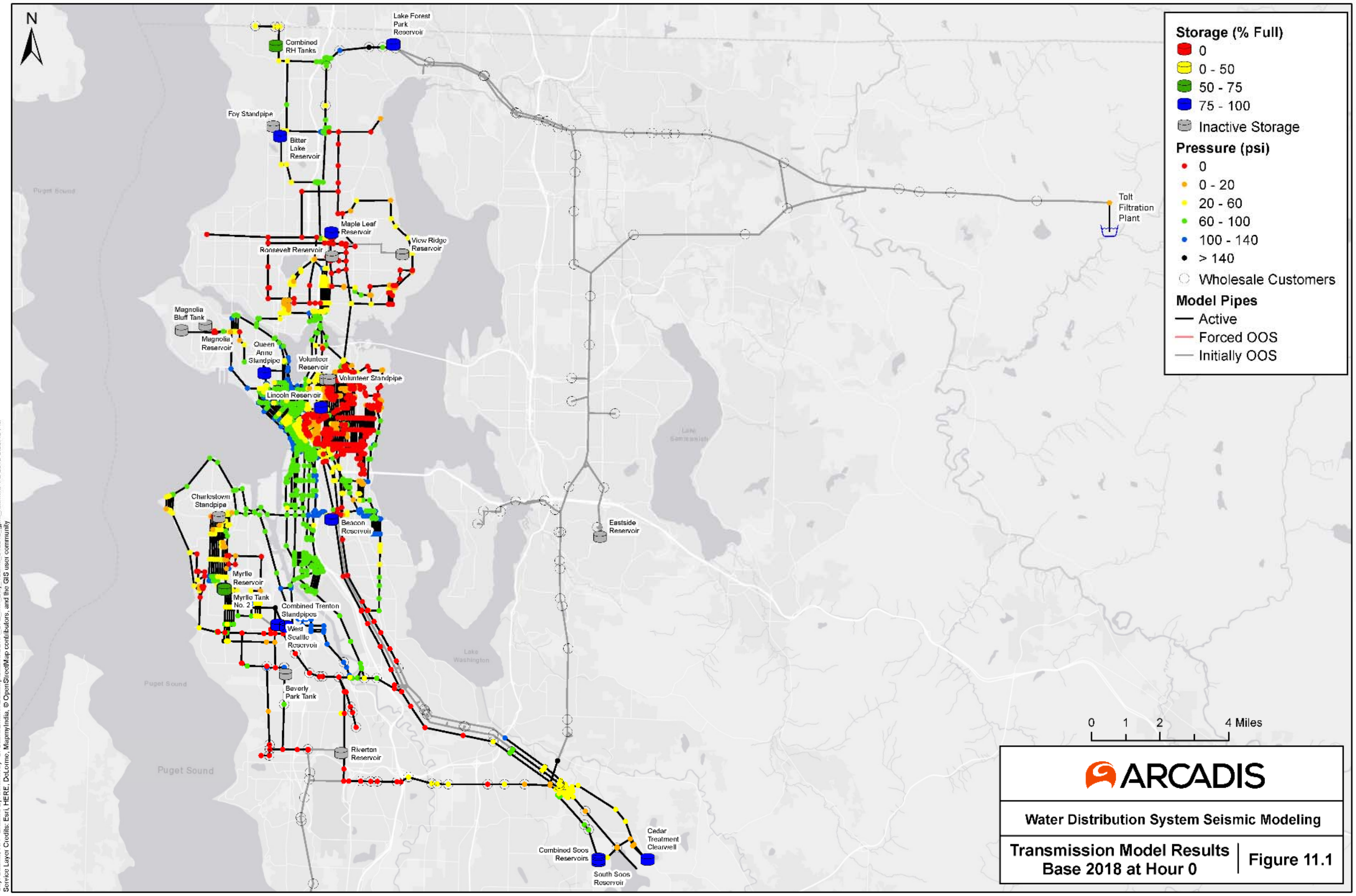

Water Distribution System Seismic Modeling

Transmission Model Results Base 2018 at Hour 0 | Figure 11.1

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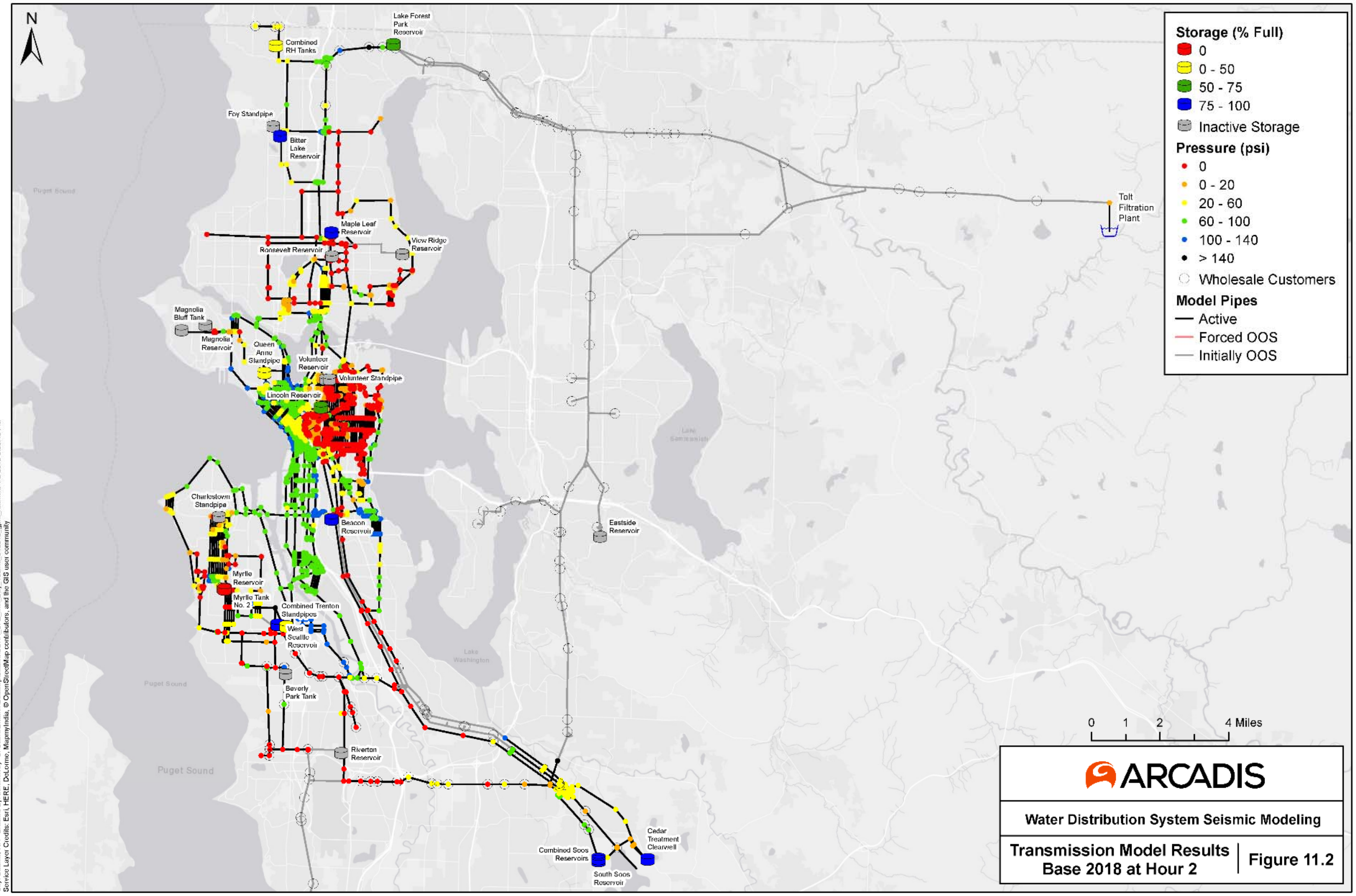
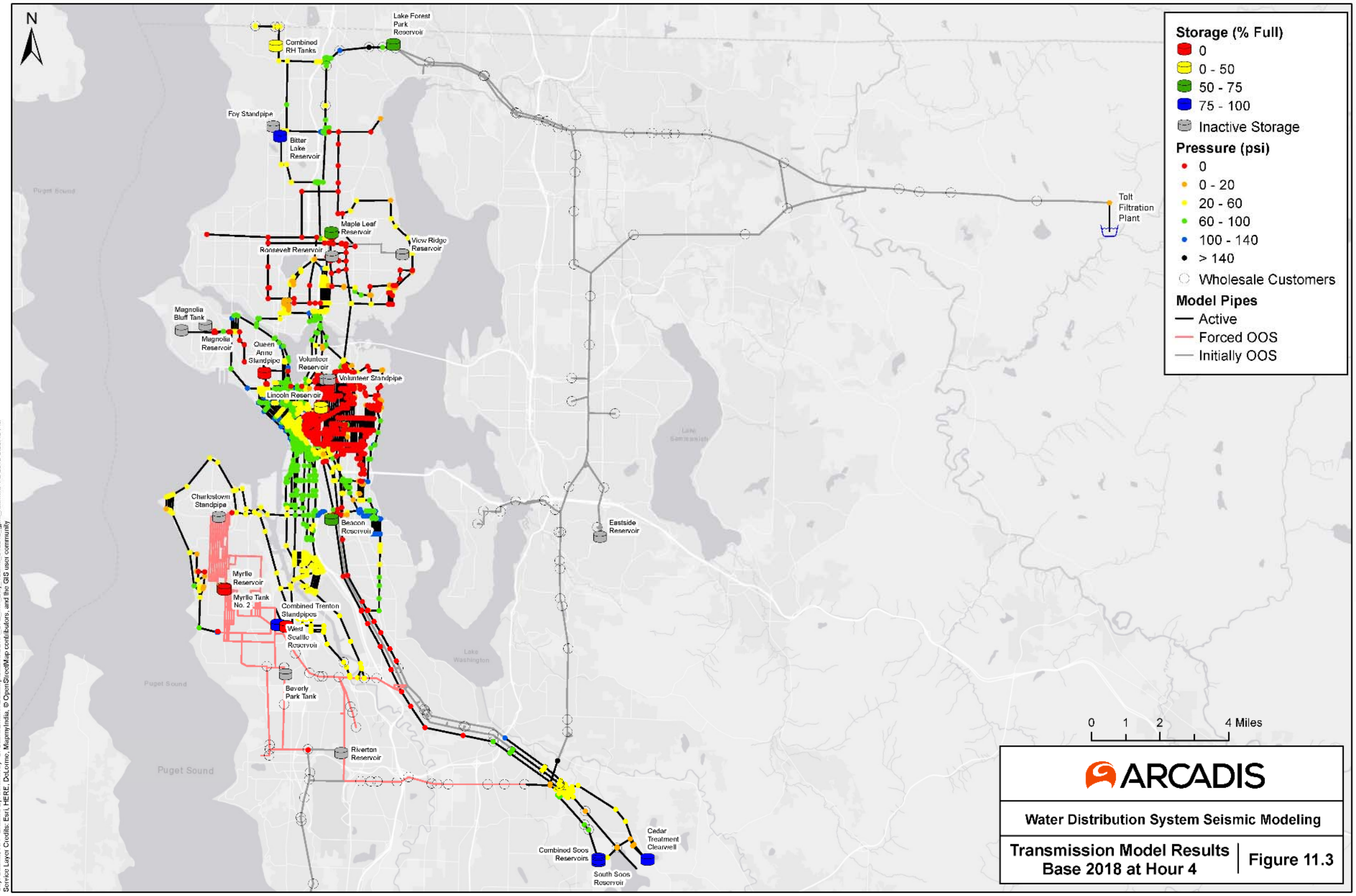


Water Distribution System Seismic Modeling

Transmission Model Results Base 2018 at Hour 2

Figure 11.2



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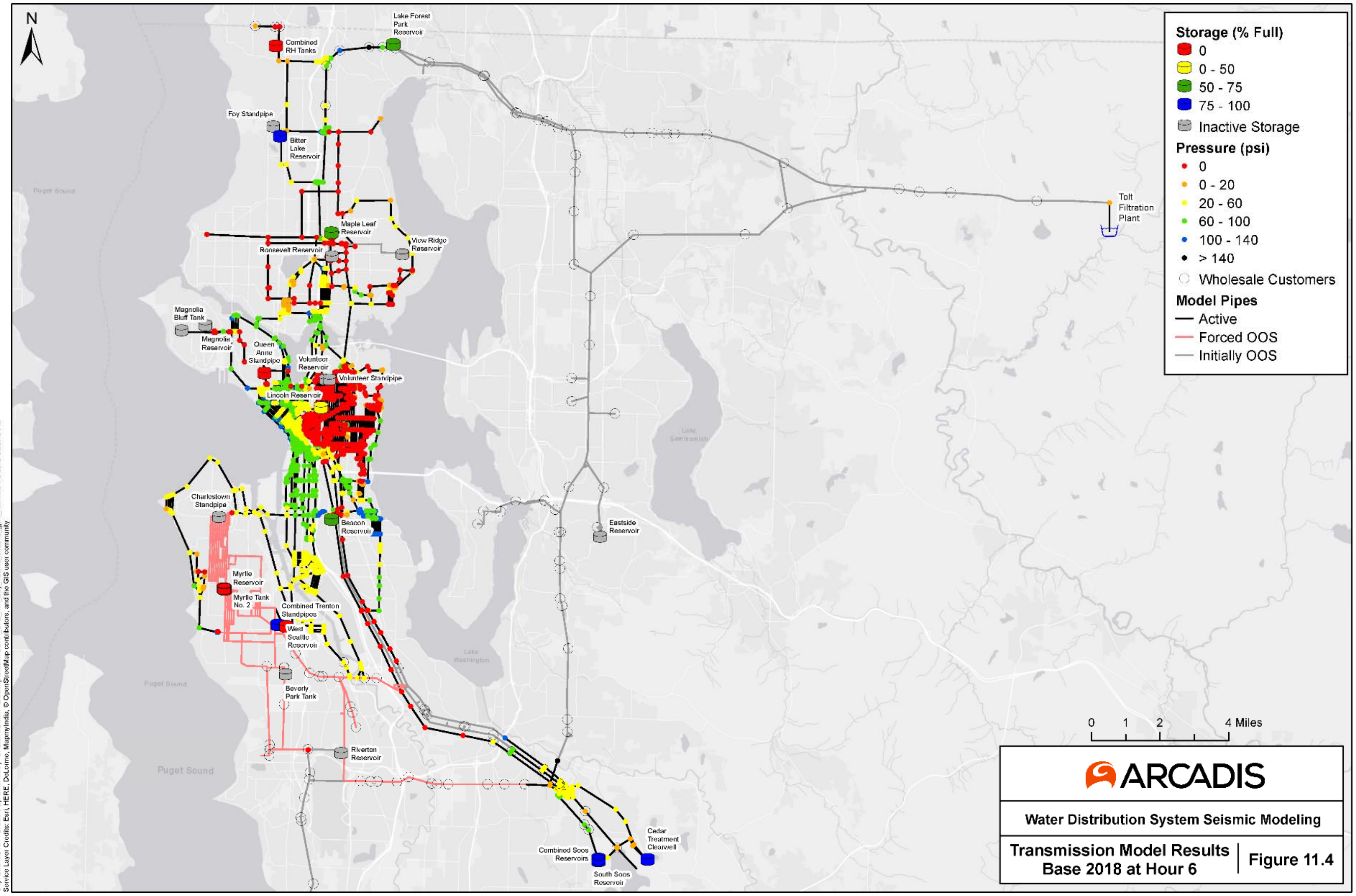

Water Distribution System Seismic Modeling

Transmission Model Results Base 2018 at Hour 6

Figure 11.4

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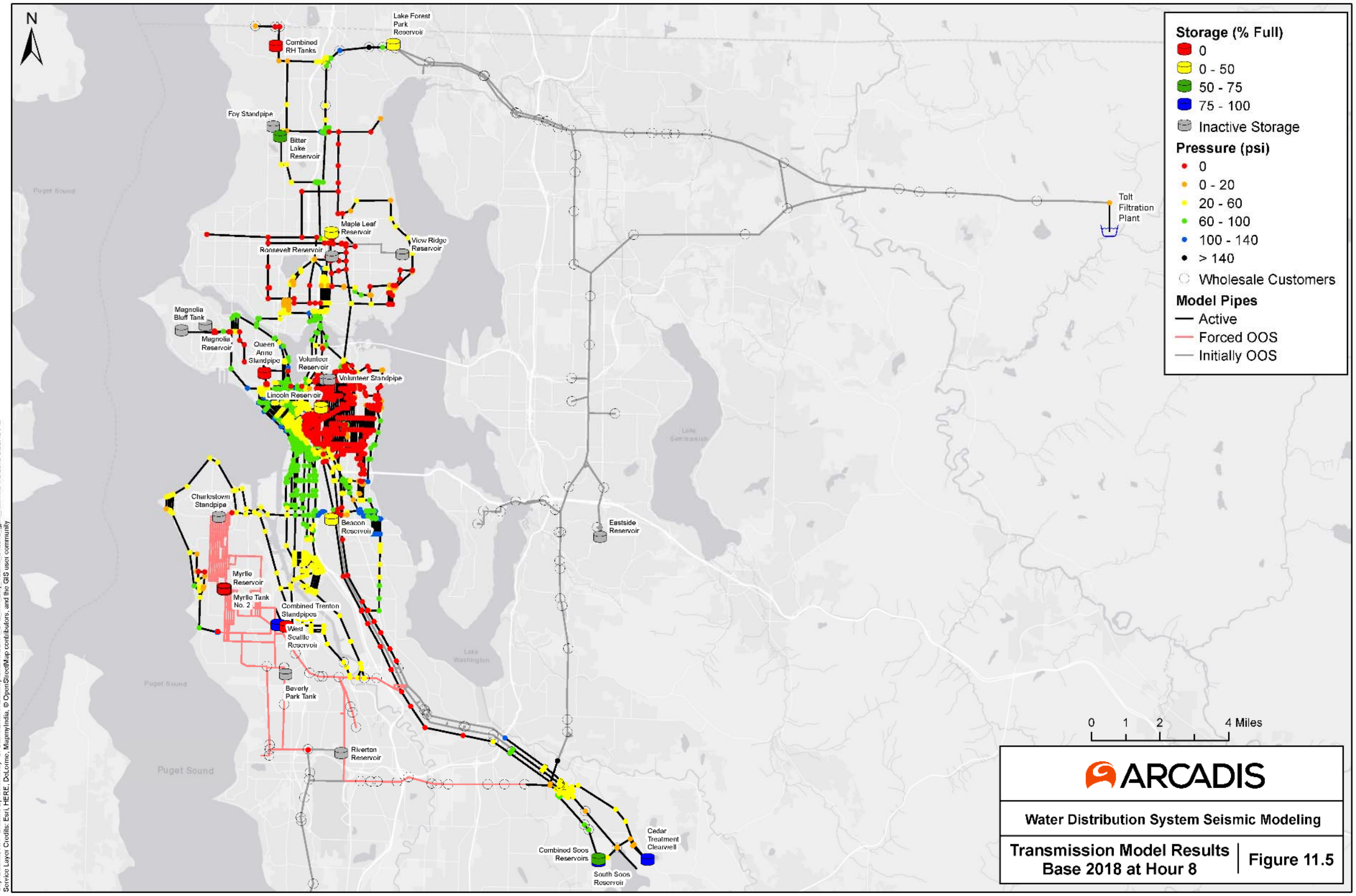

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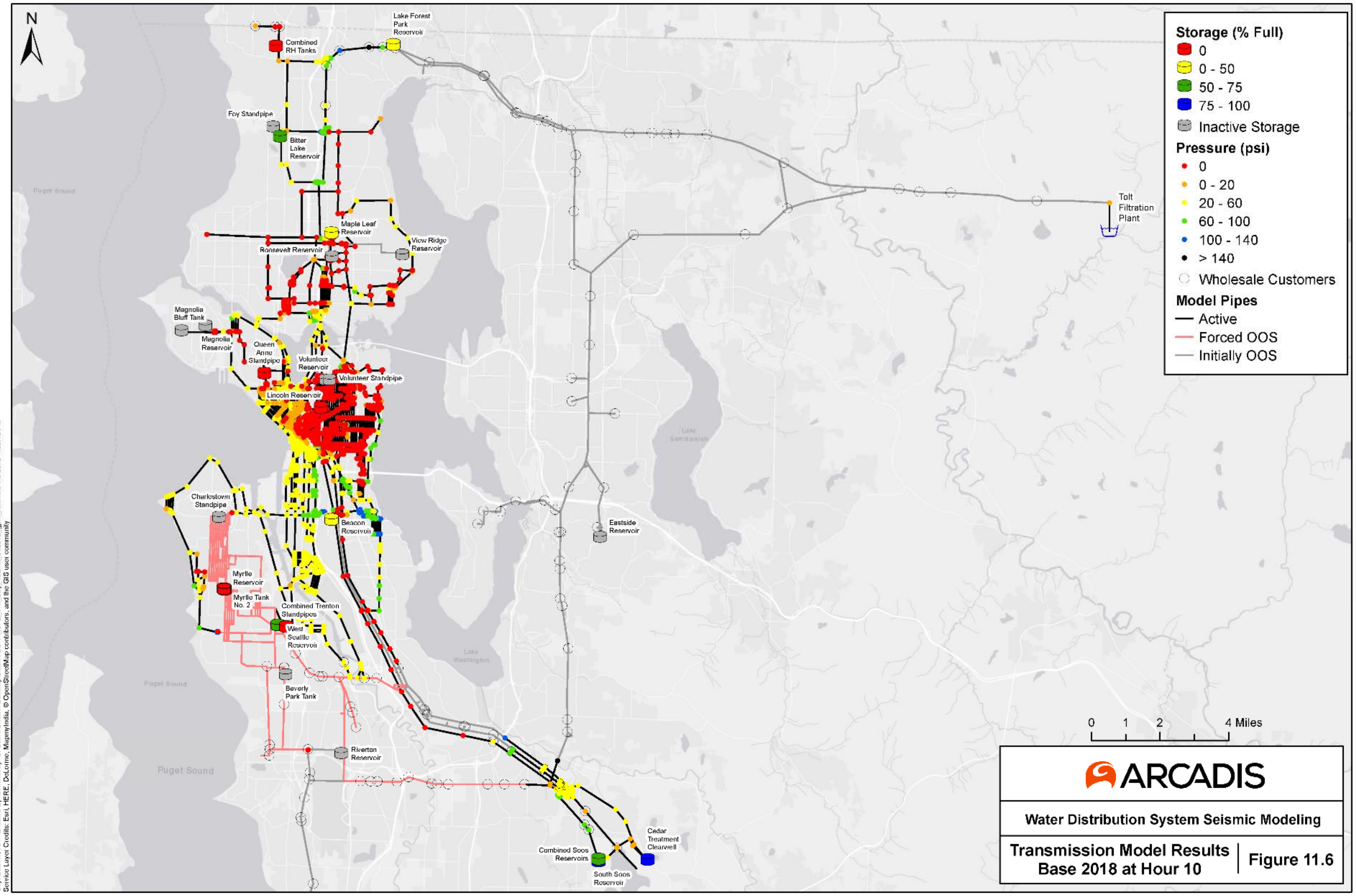

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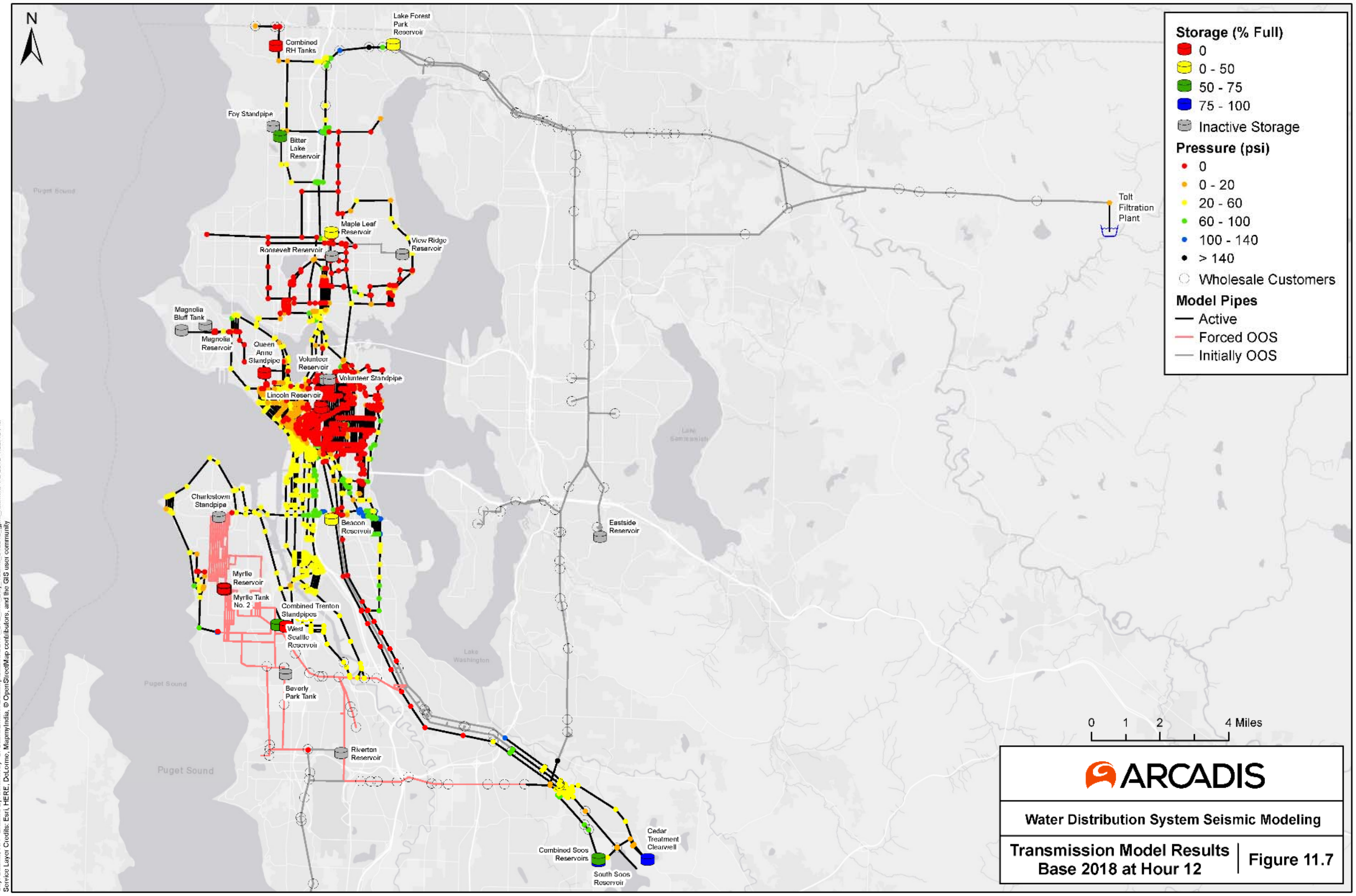
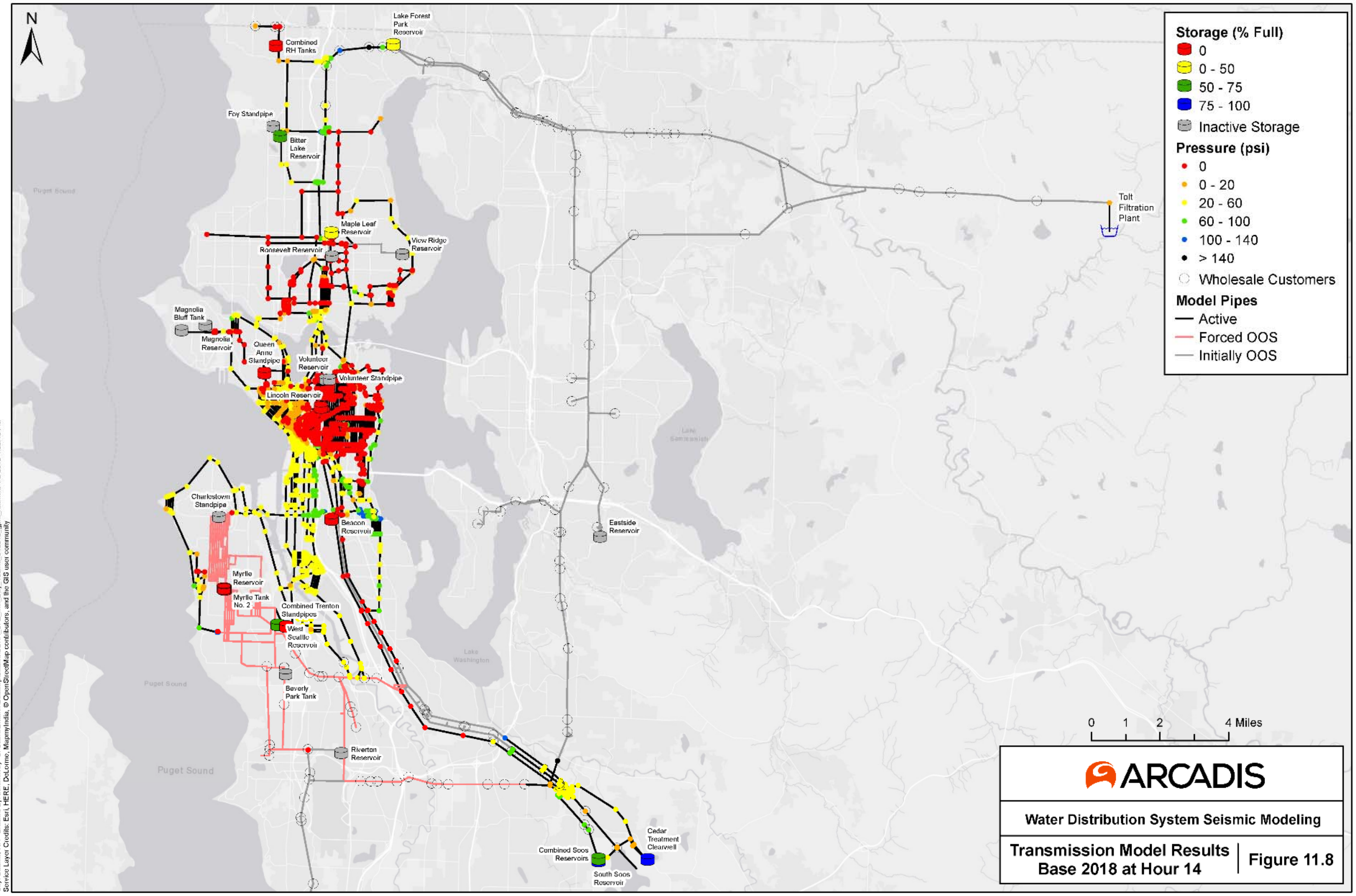
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

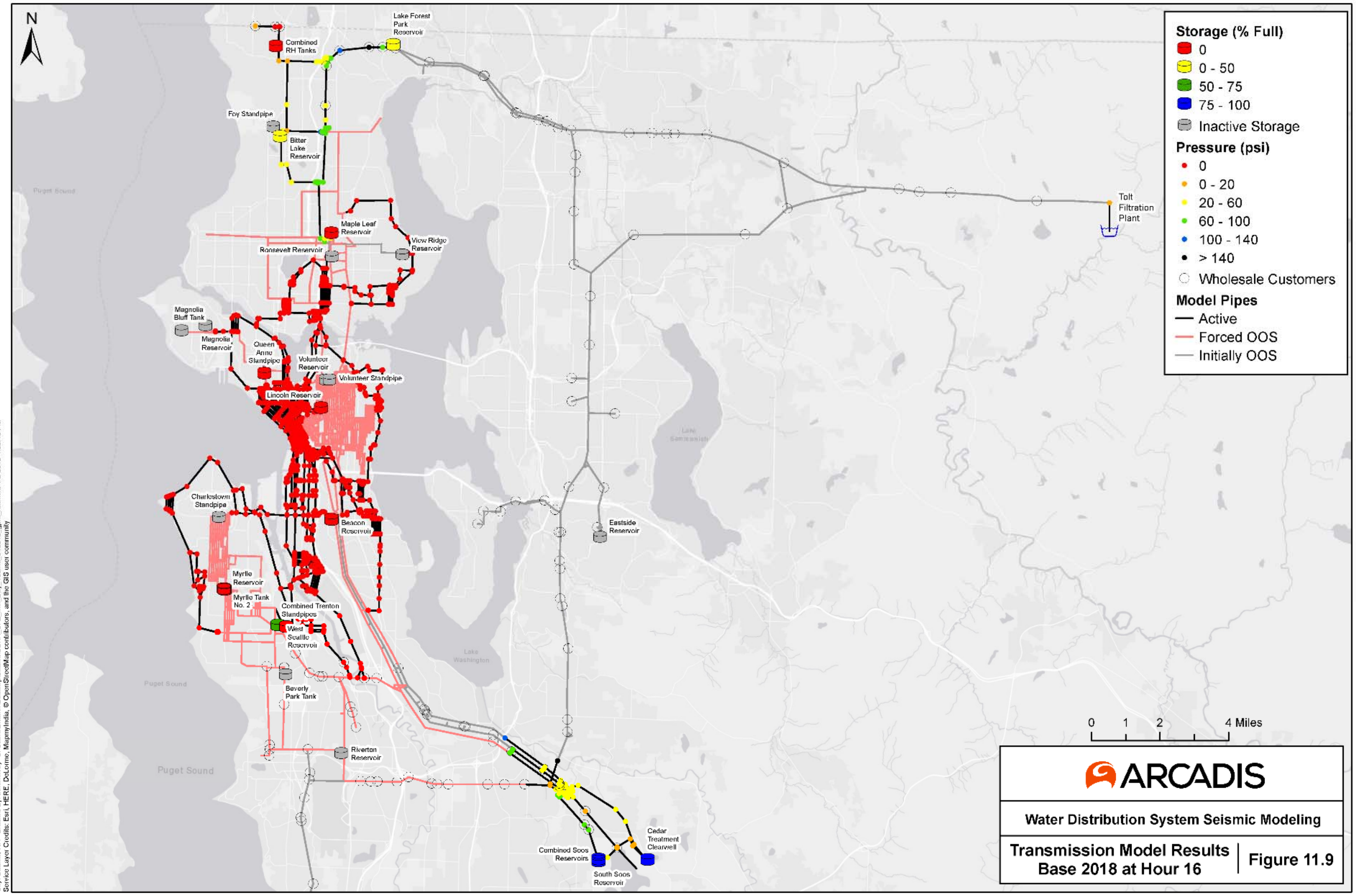

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Base 2018 at Hour 12
Figure 11.7



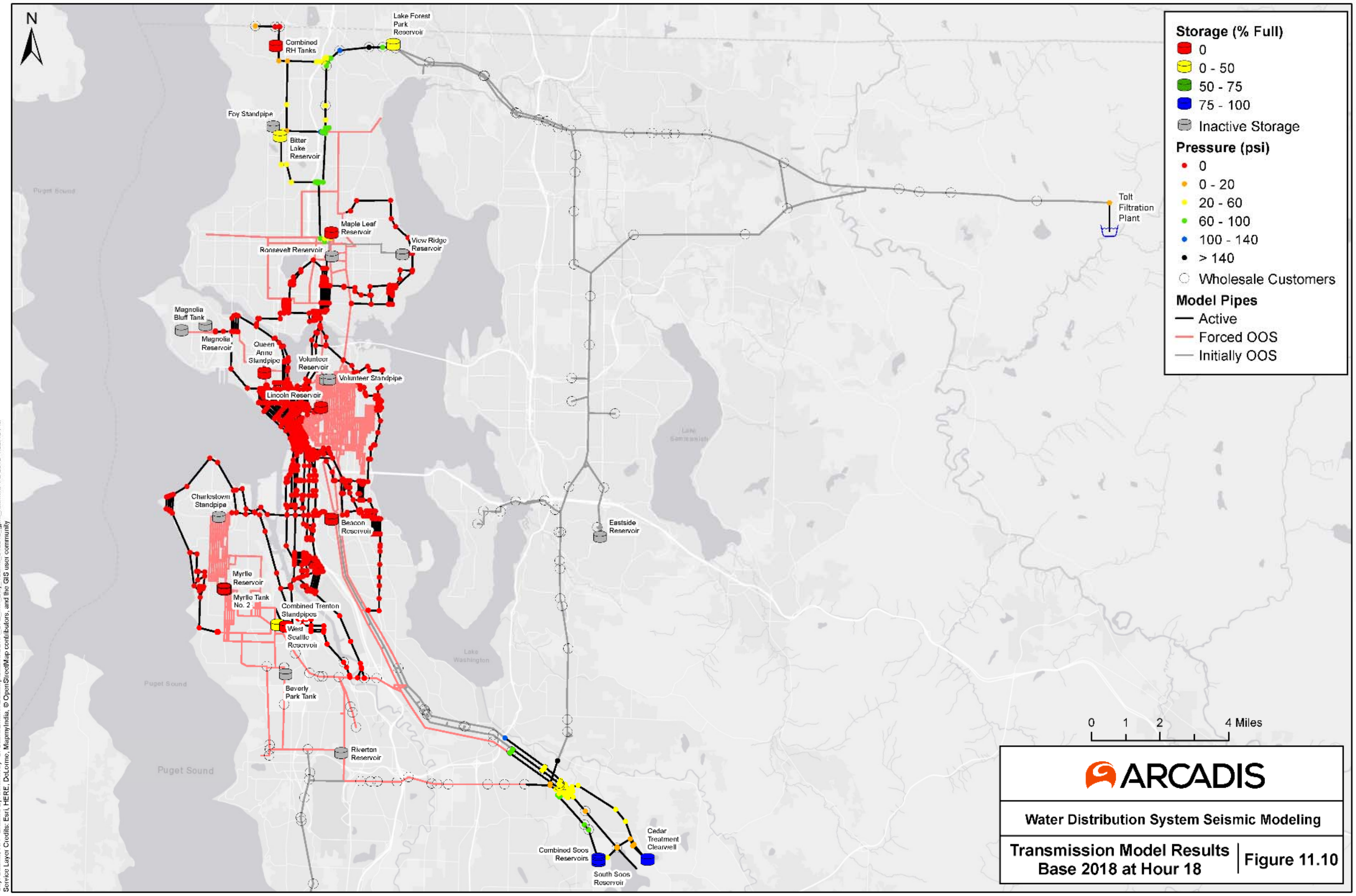
Water Distribution System Seismic Modeling

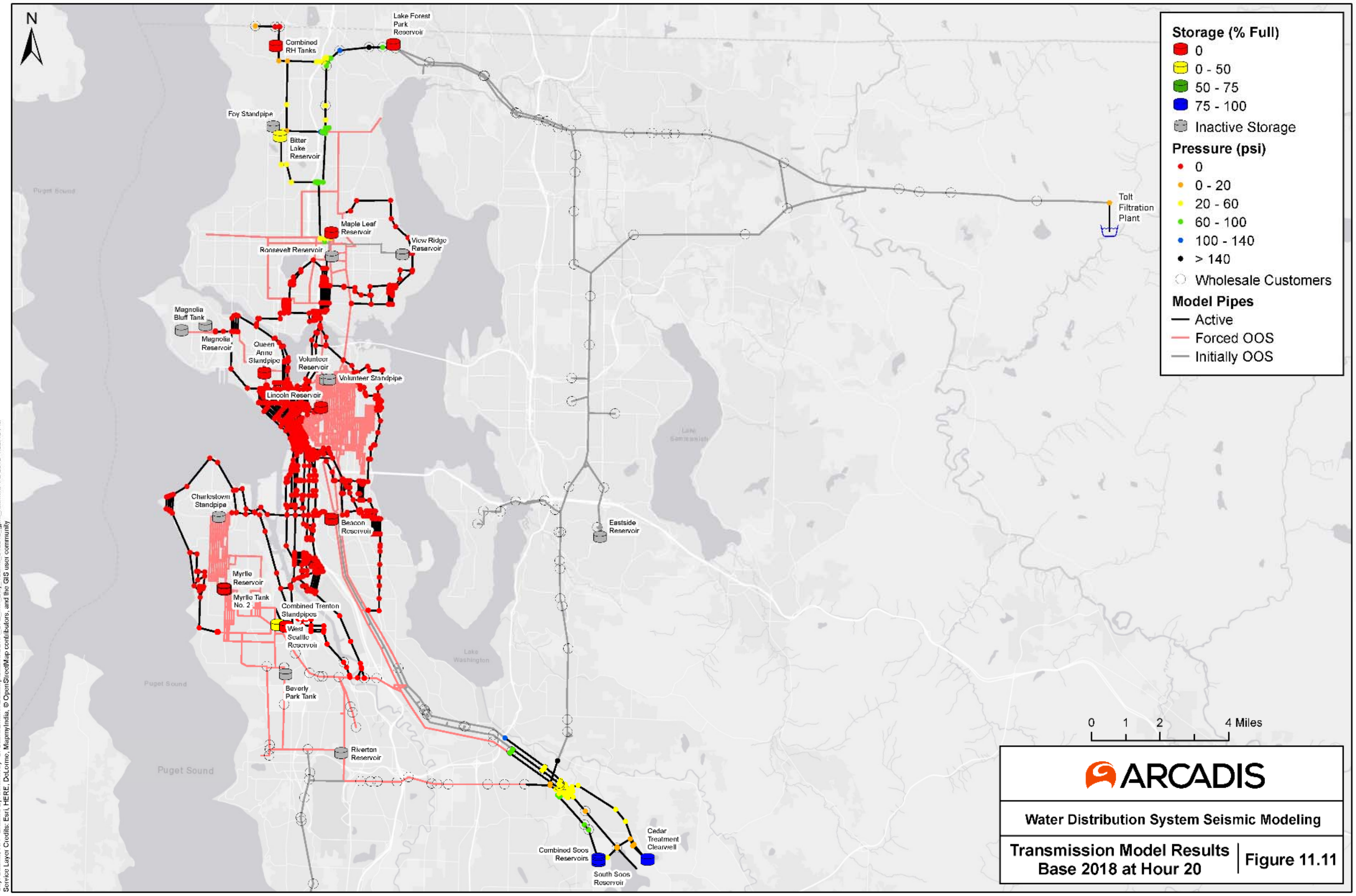
Transmission Model Results Base 2018 at Hour 14

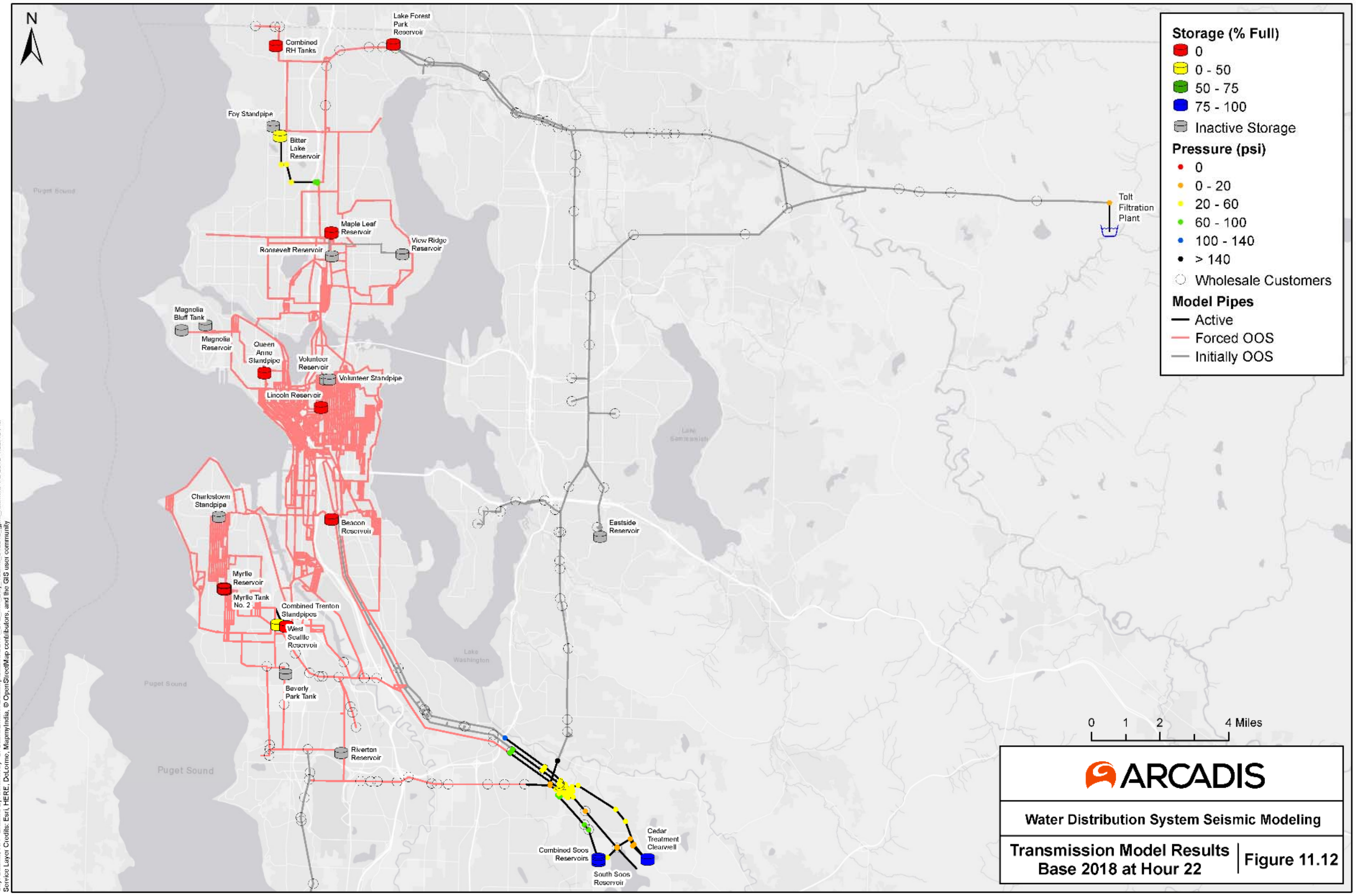
Figure 11.8



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Base 2018 at Hour 16
Figure 11.9
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish


Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Base 2018 at Hour 18
Figure 11.10


Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Base 2018 at Hour 20
Figure 11.11



Water Distribution System Seismic Modeling

Transmission Model Results Base 2018 at Hour 22

Figure 11.12

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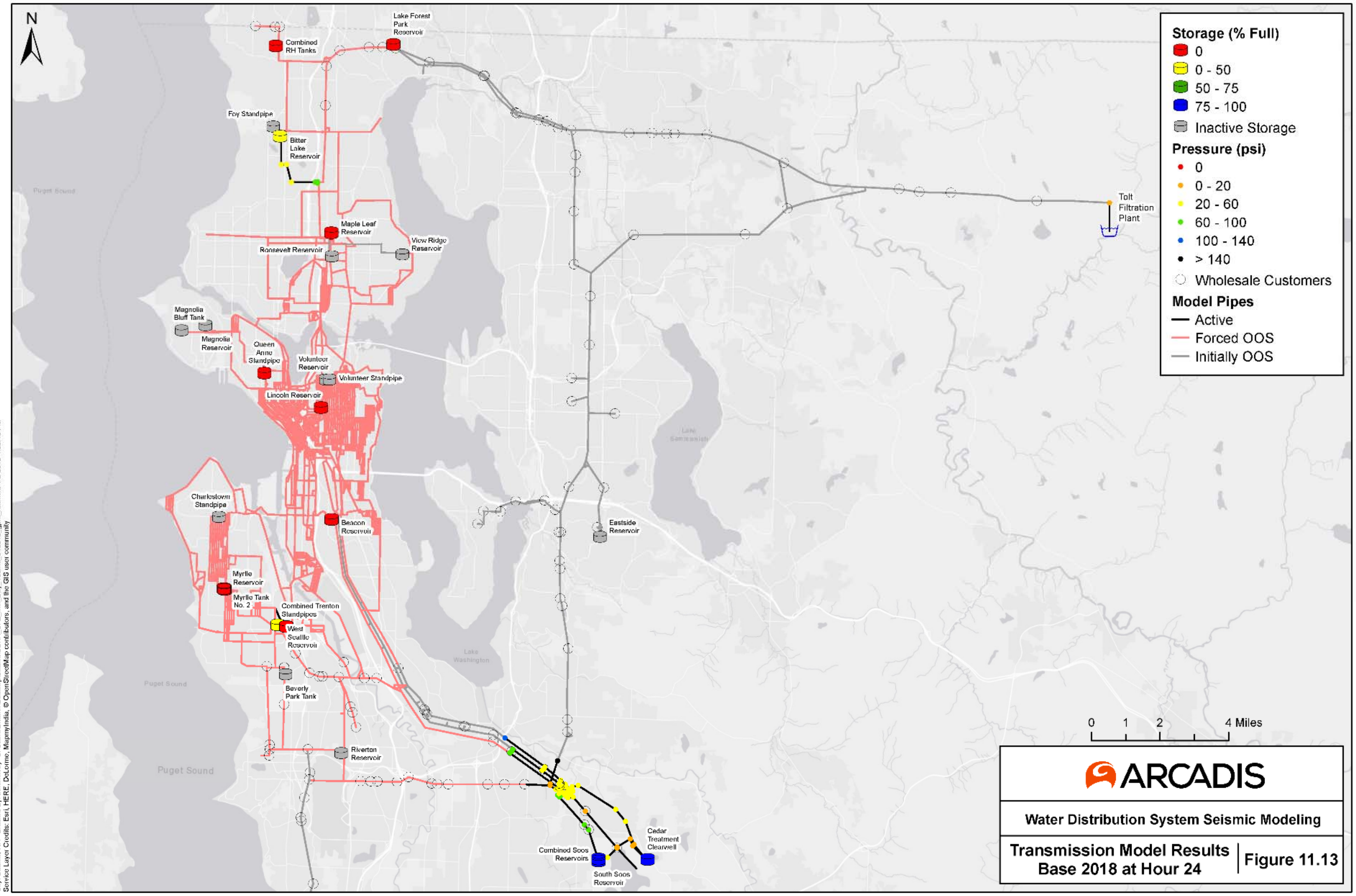

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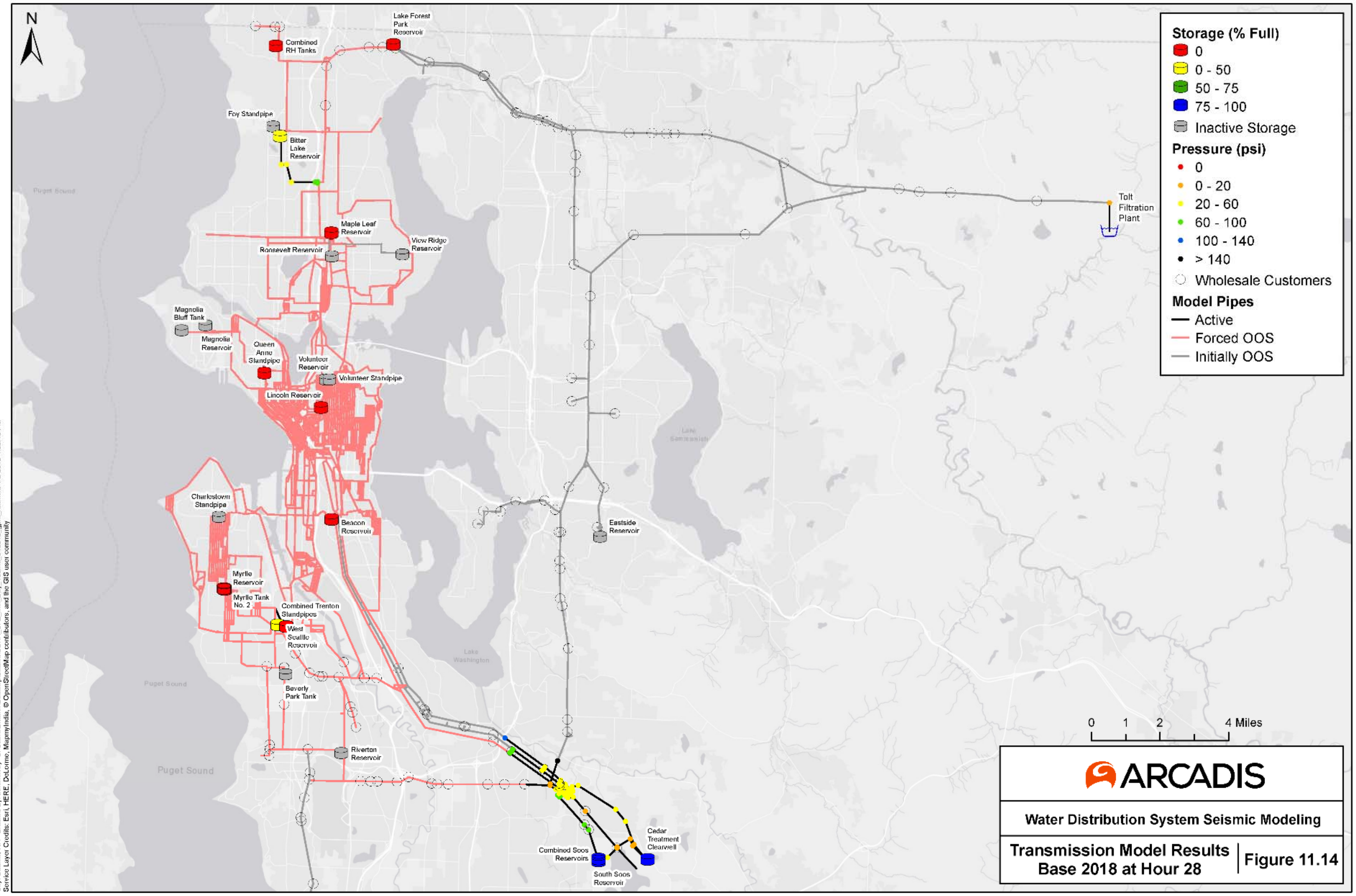
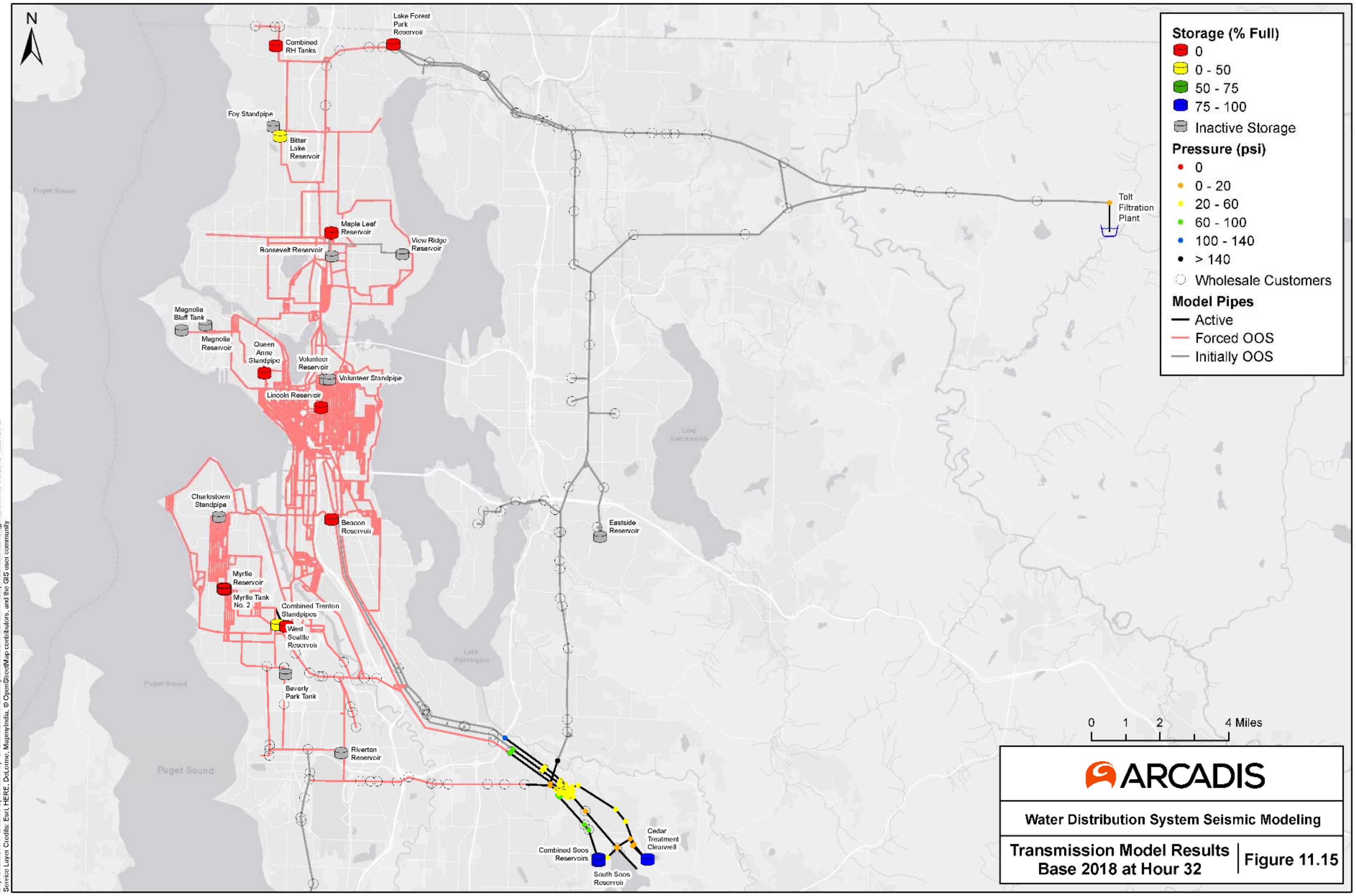


N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Base 2018 at Hour 28
Figure 11.14



Transmission Model Results Base 2018 at Hour 32
Figure 11.15

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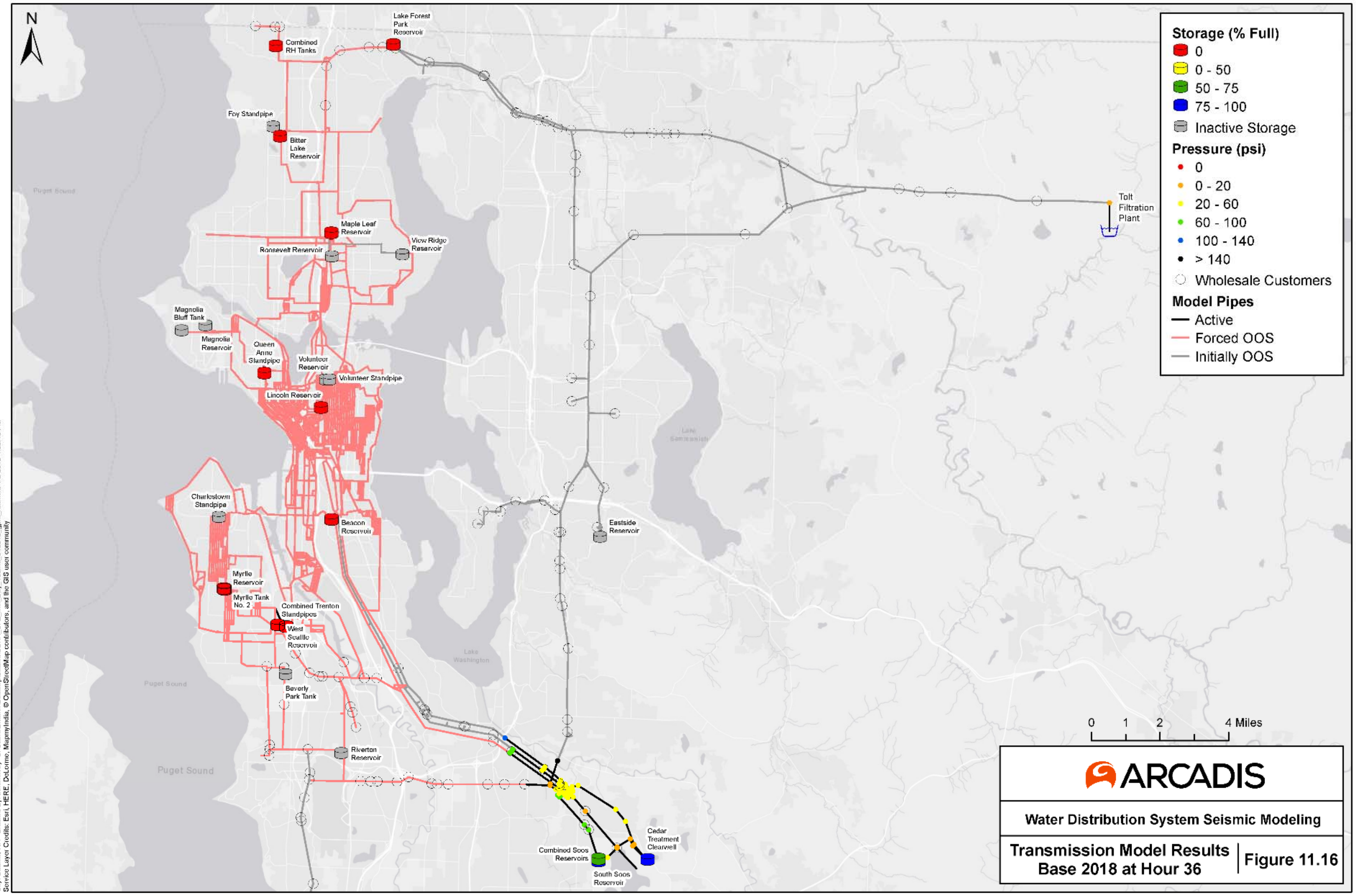
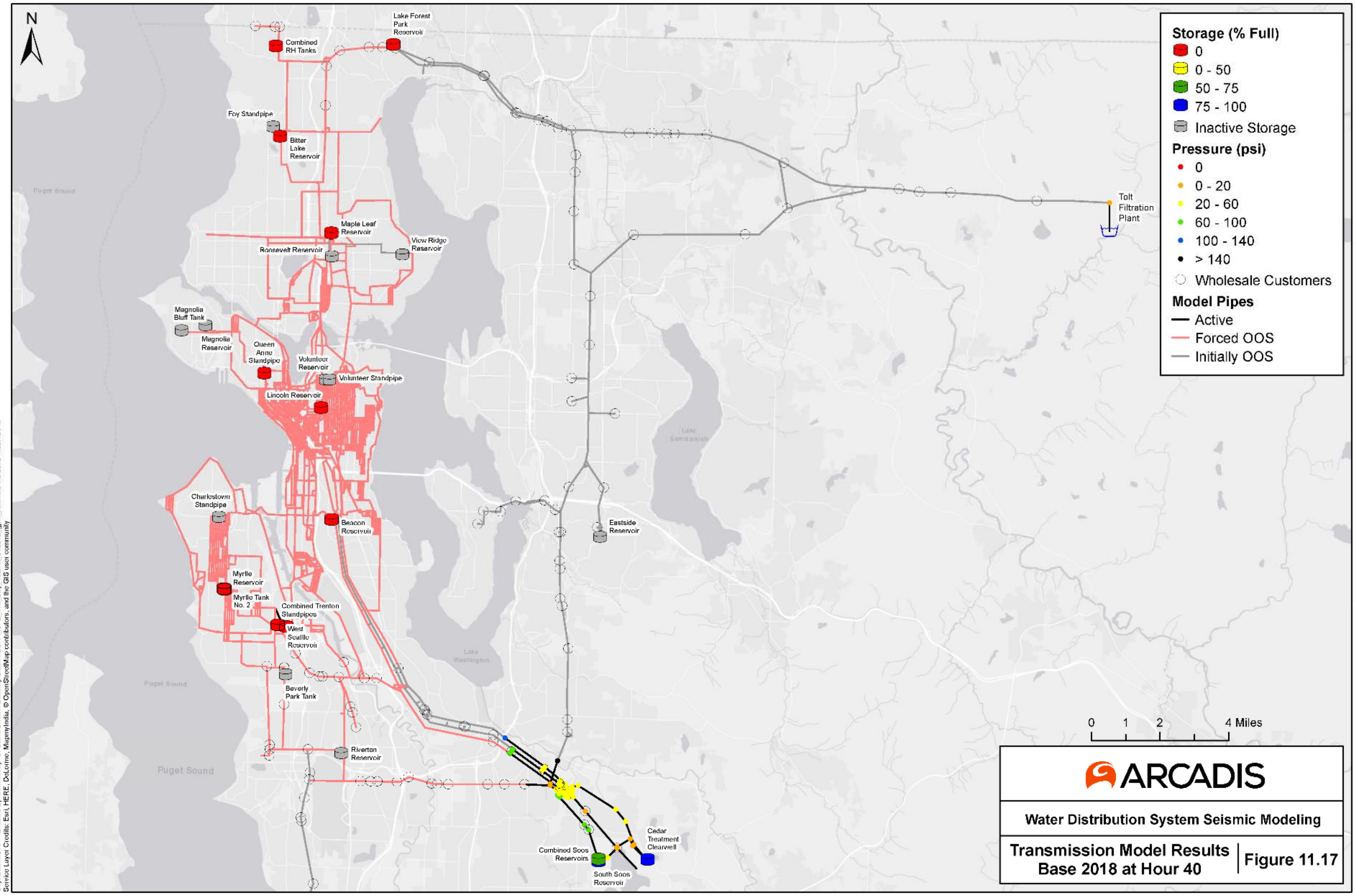

N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Base 2018 at Hour 36
Figure 11.16



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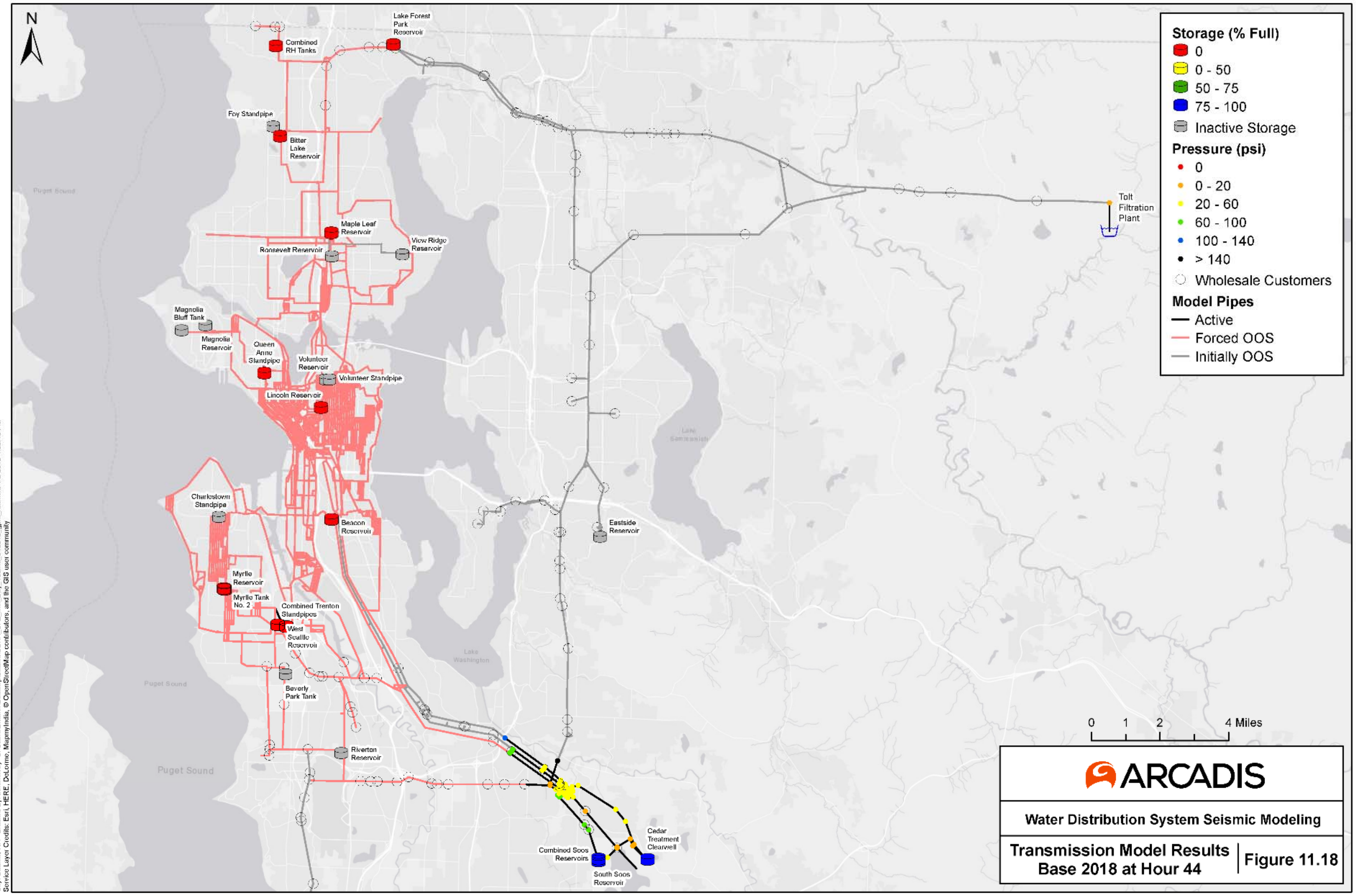

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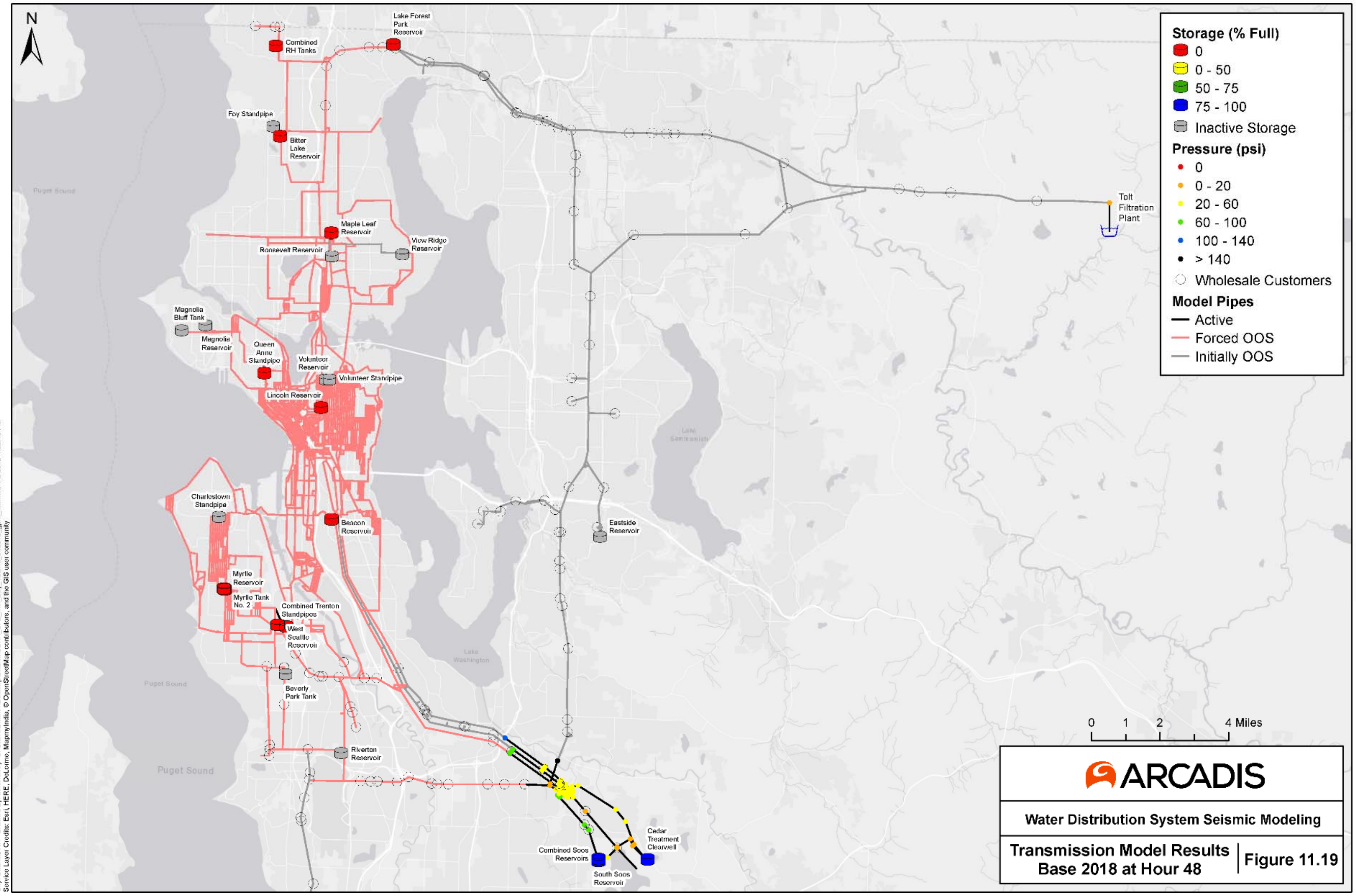
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Cedar Treatment Clearwell
Combined Soos Reservoirs
South Soos Reservoir
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Base 2018 at Hour 48
Figure 11.19

M7.0 Seattle Fault Zone Transmission Pipeline Year 2045 Improvement Case Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

4/4/2018

Seattle Fault Seismic Event
Transmission Pipeline Simulations

Case 2045 A Water from Tolt Filtration Plant cannot be conveyed west;
Eastside Supply Line is open; Tolt Eastside Pipes 7623, 7113, 7079, 7509 are closed;
Facility upgrades are the same as distribution system Case 1;
Water from Control Works (Cedar System) cannot be conveyed into the distibution system.

Model Results

Time (hrs)	Total System Demand (gpm)	Emitter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	337,537	279,583	57,953	75%	299.5
3	301,701	247,840	53,862	73%	242.3
12	219,606	177,790	41,815	49%	107.2
22	68,141	41,920	26,221	11%	41.0
32	54,703	31,501	23,202	9%	14.2
48	24,771	17,638	7,133	6%	11.6

Model Regions Forced Out of Service During Simulation

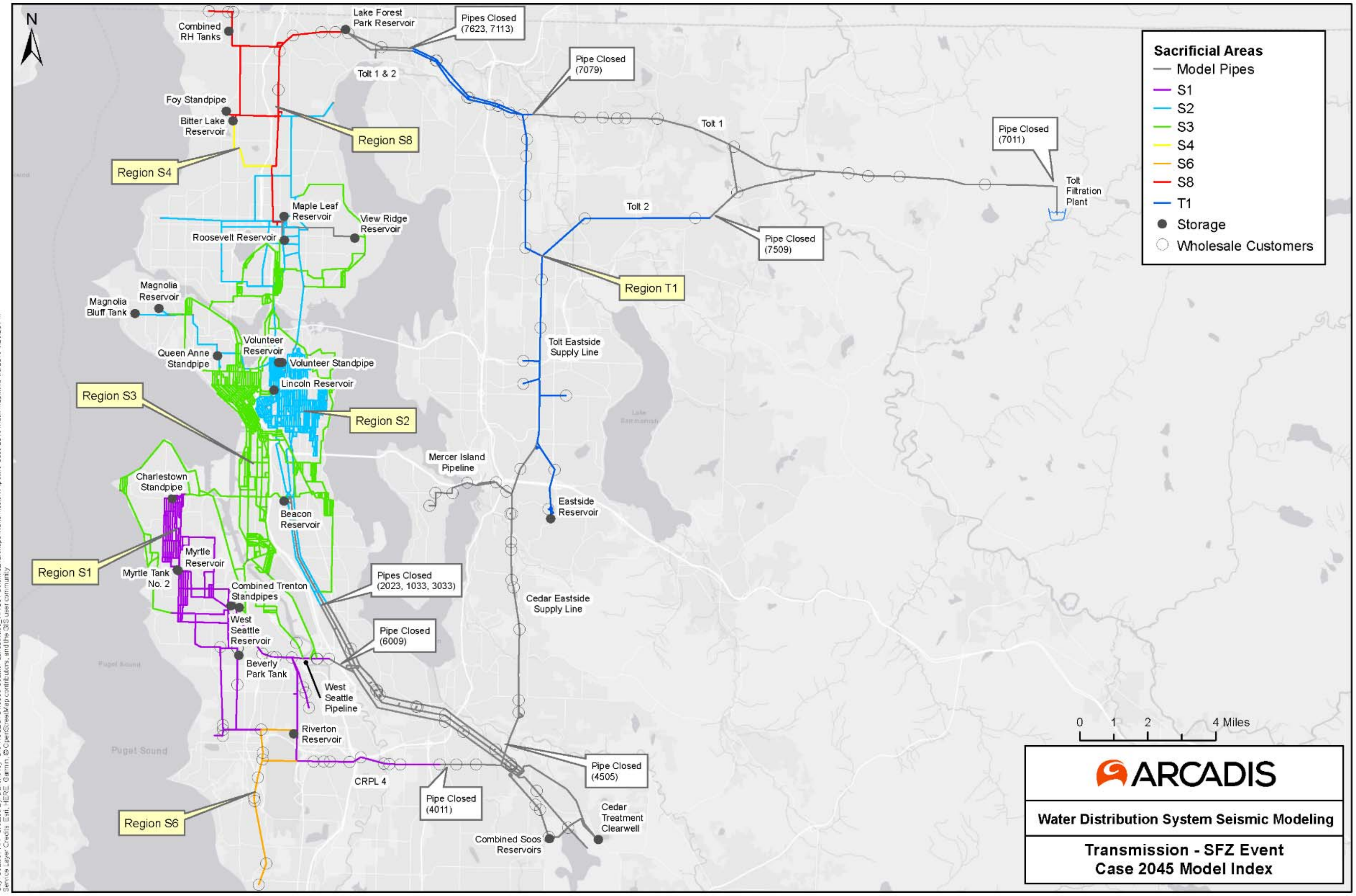
Time	Region
9	S6
15	S1
15	S2
26	S4
26	S3
26	S8
33	T1

Model Simulation Notes

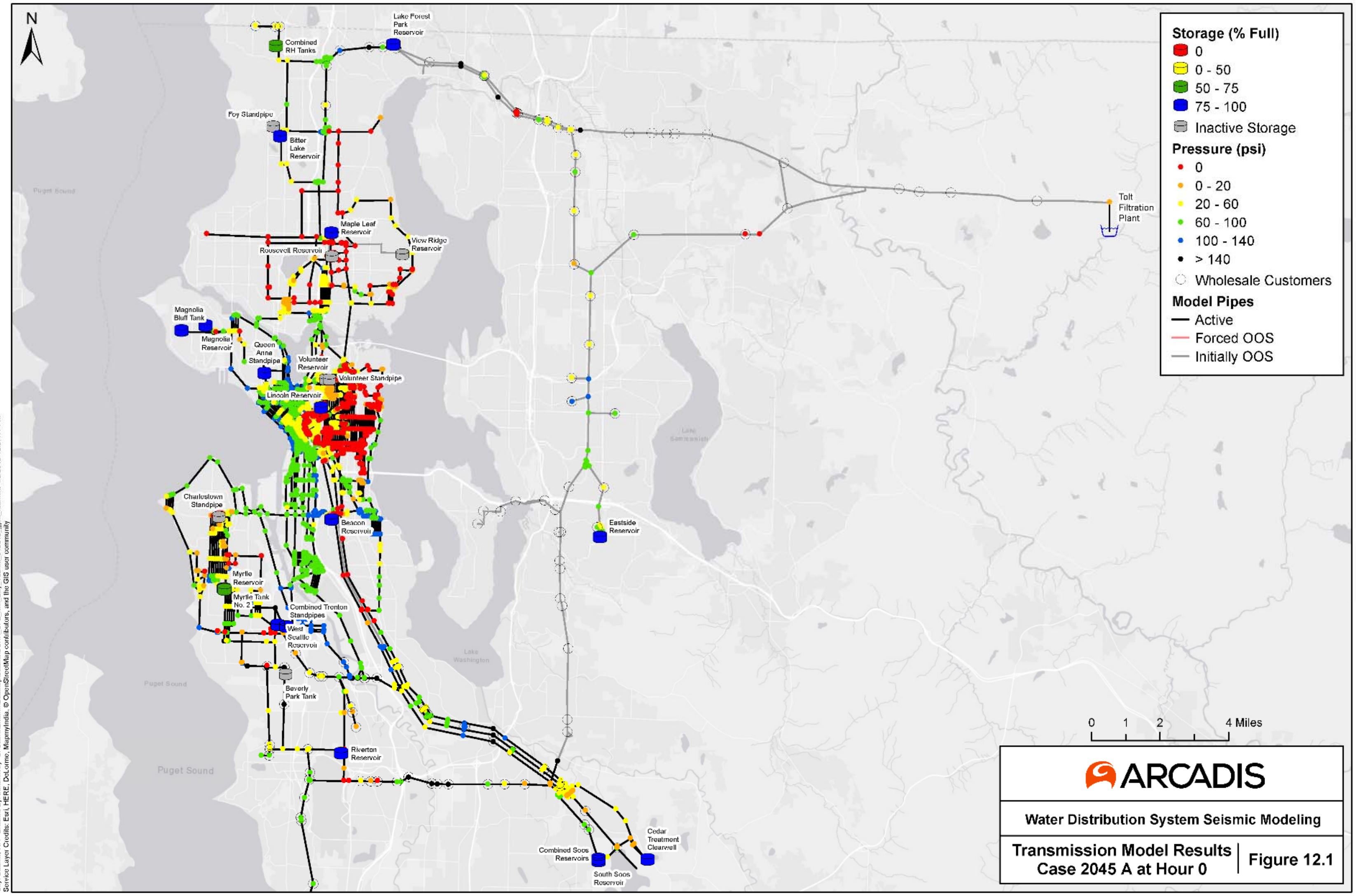
1. *All wholesale customers assumed to start with 1.8 multiplier (max day demands)*
2. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
3. *Total Model Demands with elevated wholesale customers is 91,957 gpm*
4. *Satisfied Demands assume junction pressure greater than 0 psi*
5. *System Positive Pressure based on number of junctions above 0 psi out of* the entire model

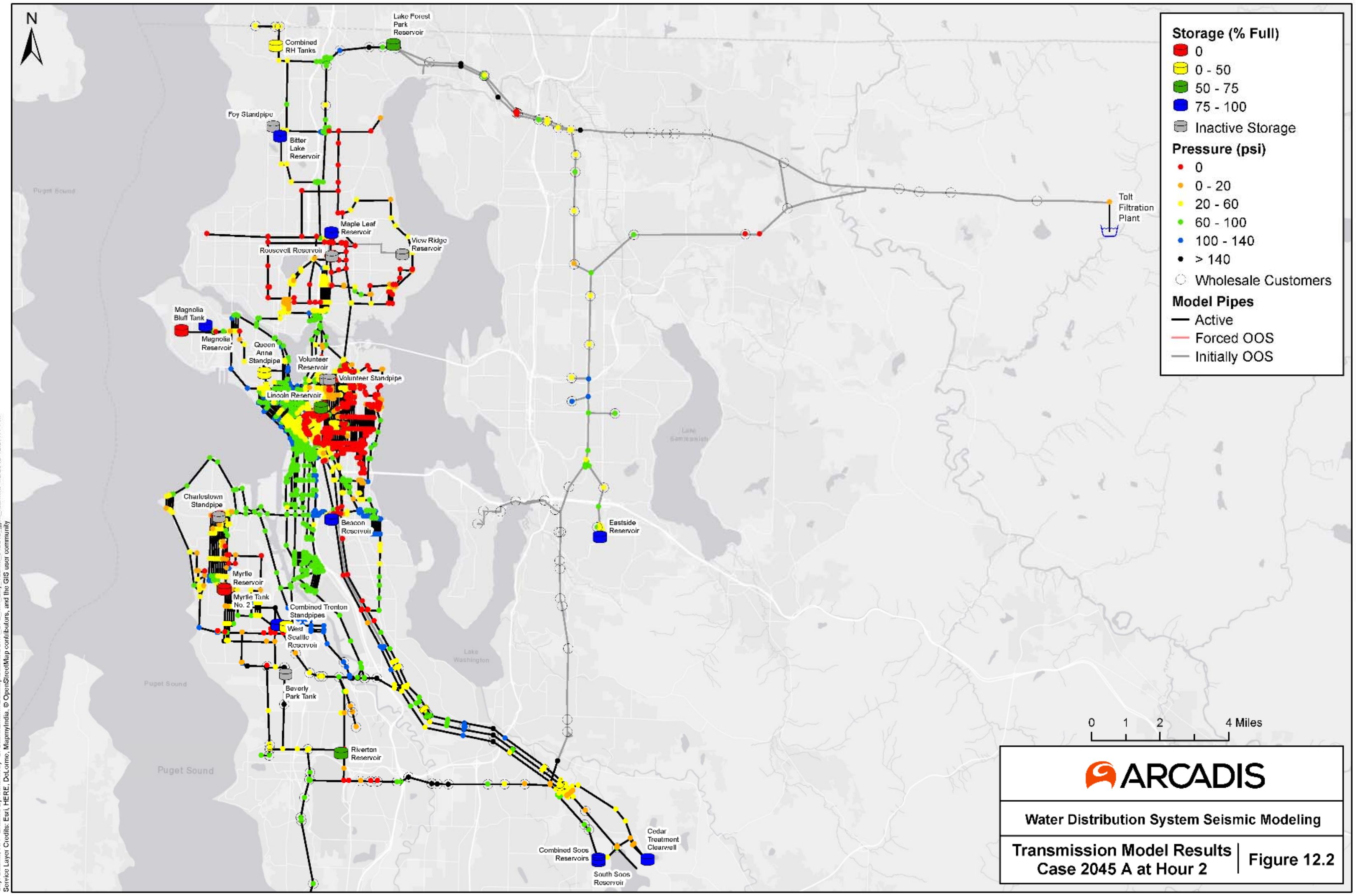
Model Results Figure Index

Fig. 12.1	Hr 0	Fig. 12.5	Hr 8	Fig. 12.9	Hr 16	Fig. 12.13	Hr 24	Fig. 12.17	Hr 40
Fig. 12.2	Hr 2	Fig. 12.6	Hr 10	Fig. 12.10	Hr 18	Fig. 12.14	Hr 28	Fig. 12.18	Hr 44
Fig. 12.3	Hr 4	Fig. 12.7	Hr 12	Fig. 12.11	Hr 20	Fig. 12.15	Hr 32	Fig. 12.19	Hr 48
Fig. 12.4	Hr 6	Fig. 12.8	Hr 14	Fig. 12.12	Hr 22	Fig. 12.16	Hr 36		

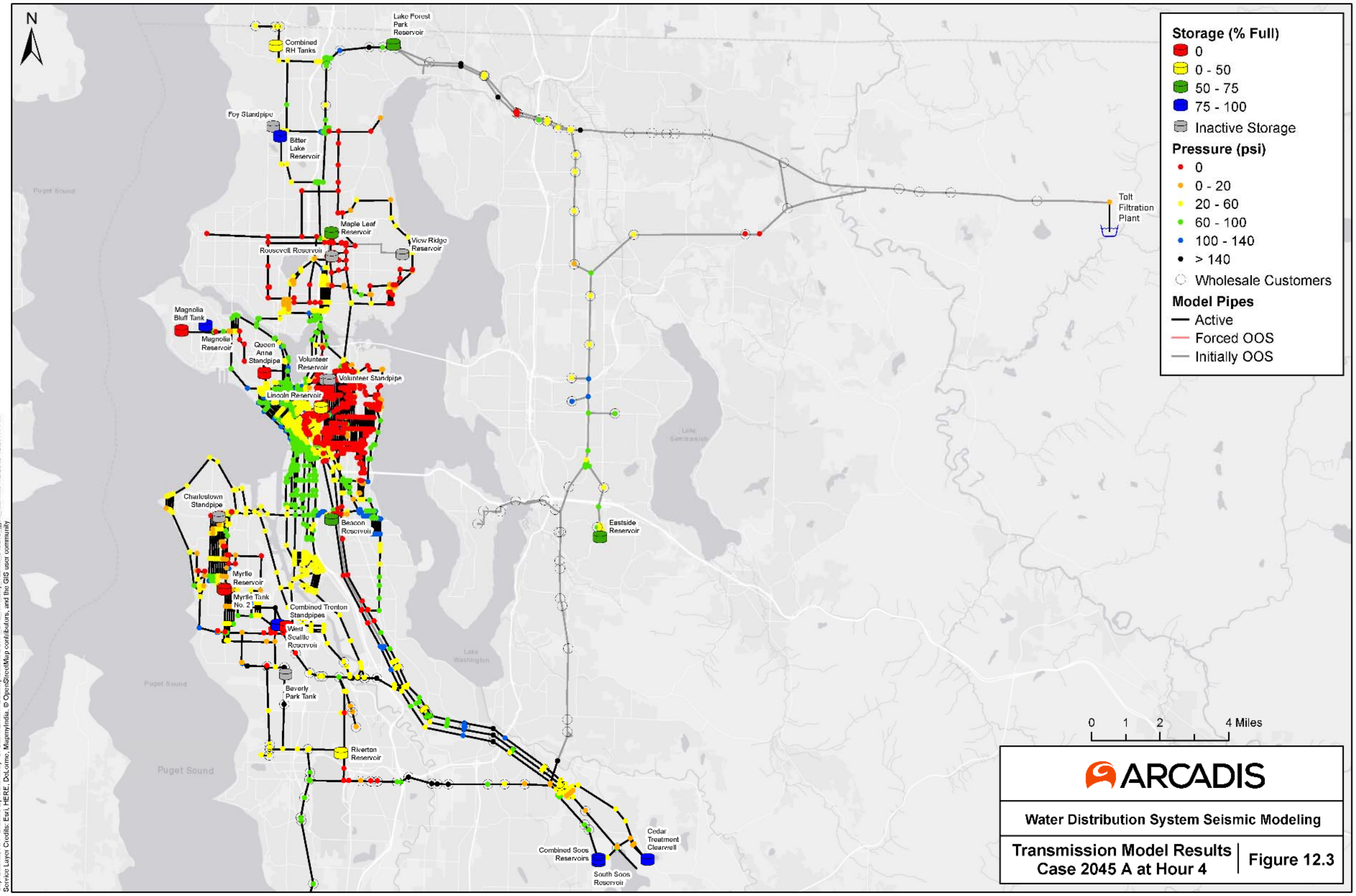


N
Sacrificial Areas
Model Pipes
S1
S2
S3
S4
S6
S8
T1
Storage
Wholesale Customers
Combined RH Tanks
Lake Forest Park Reservoir
Pipes Closed (7623, 7113)
Tolt 1 & 2
Pipe Closed (7079)
Foy Standpipe
Bitter Lake Reservoir
Region S8
Region S4
Tolt 1
Pipe Closed (7011)
Tolt Filtration Plant
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Tolt 2
Pipe Closed (7509)
Region T1
Magnolia Reservoir
Magnolia Bluff Tank
Volunteer Reservoir
Queen Anne Standpipe
Volunteer Standpipe
Tolt Eastside Supply Line
Lincoln Reservoir
Region S3
Region S2
Mercer Island Pipeline
Charlestown Standpipe
Eastside Reservoir
Beacon Reservoir
Region S1
Myrtle Reservoir
Myrtle Tank No. 2
Pipes Closed (2023, 1033, 3033)
Combined Trenton Standpipes
Cedar Eastside Supply Line
West Seattle Reservoir
Pipe Closed (6009)
Beverly Park Tank
West Seattle Pipeline
Riverton Reservoir
Puget Sound
Pipe Closed (4505)
CRPL 4
Pipe Closed (4011)
Region S6
Cedar Treatment Clearwell
Combined Soos Reservoirs
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission - SFZ Event
Case 2045 Model Index

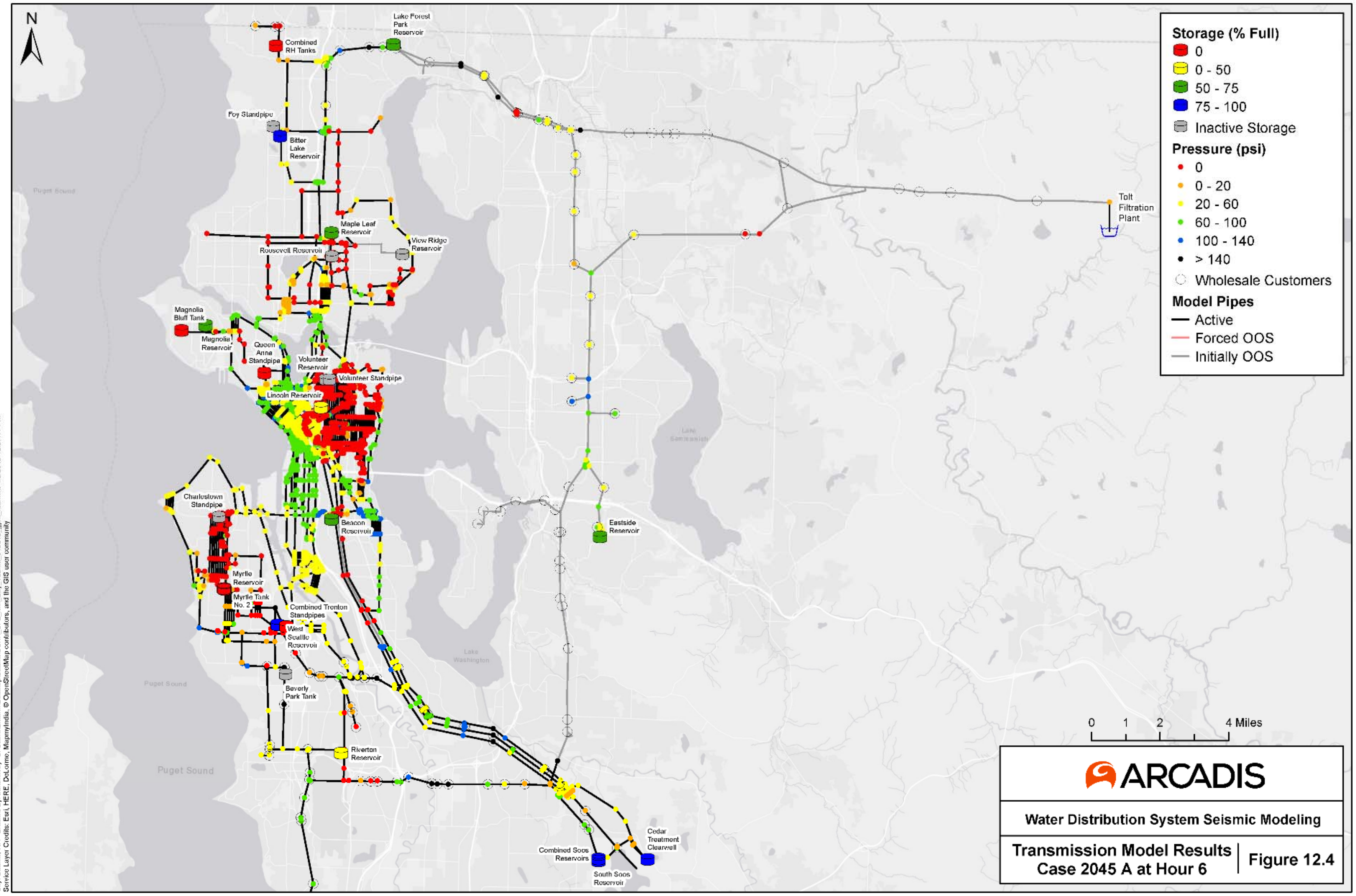

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Case 2045 A at Hour 0
Figure 12.1



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Case 2045 A at Hour 2
Figure 12.2



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 4
Figure 12.3



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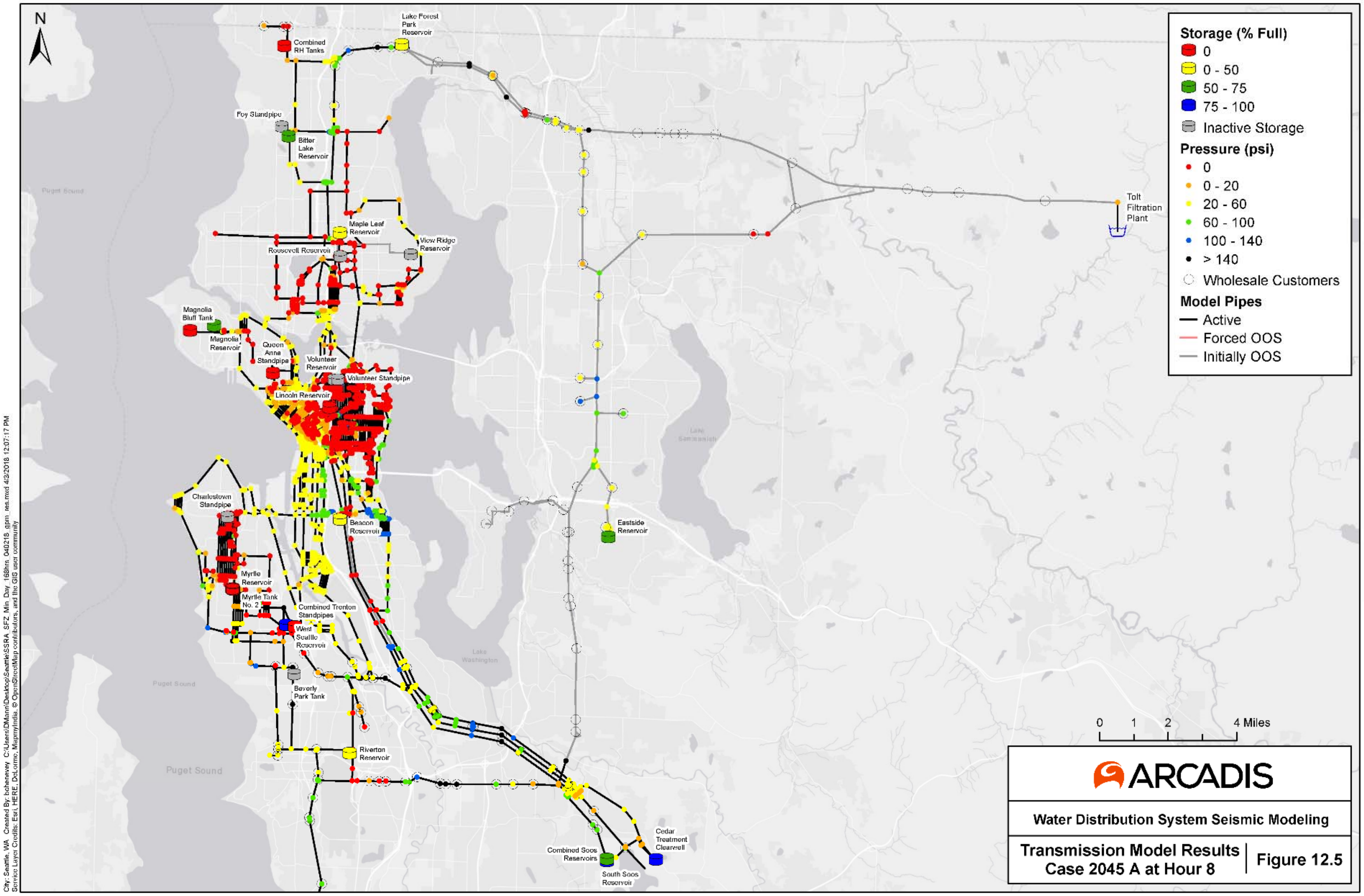
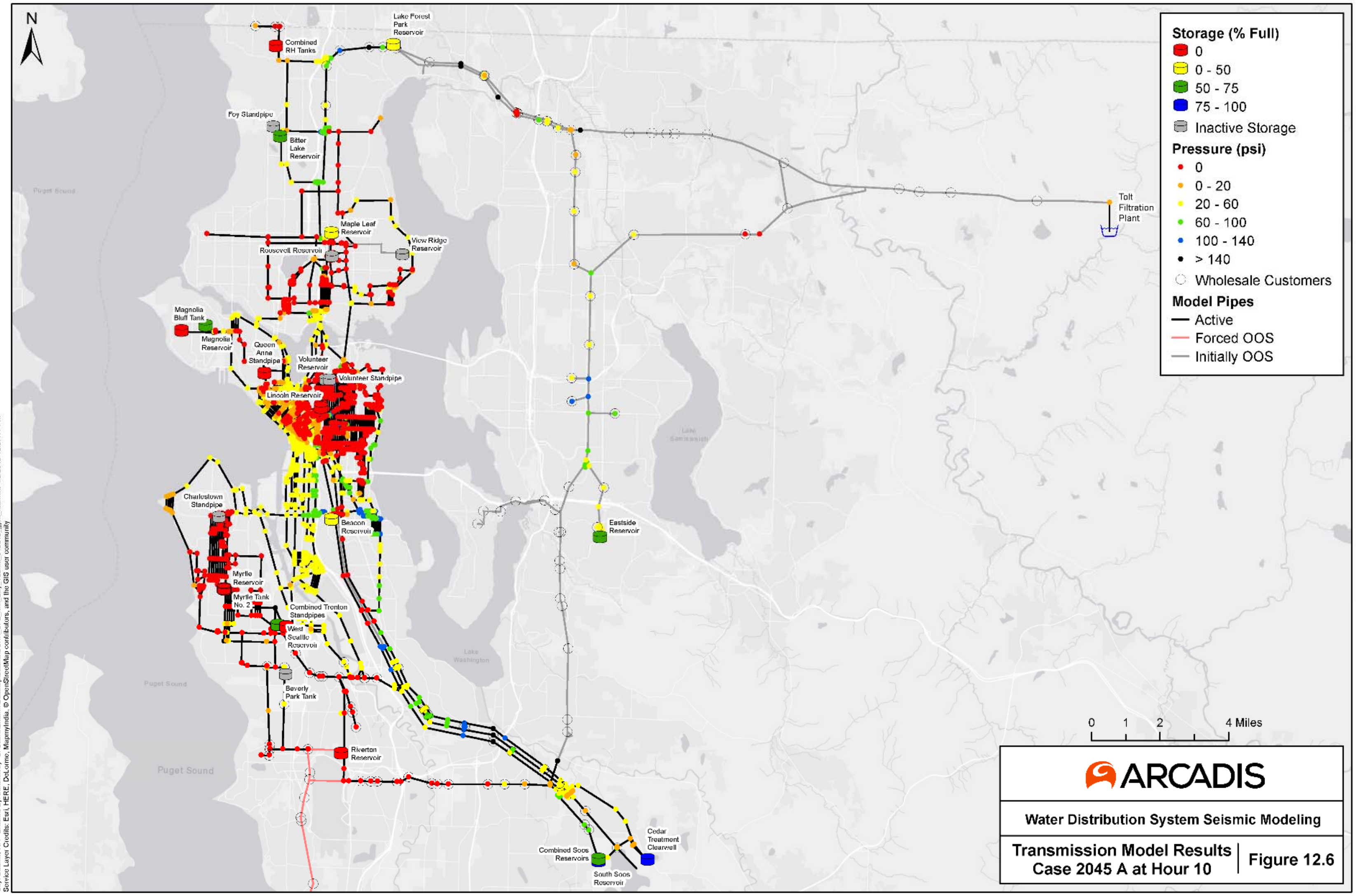


Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 8
Figure 12.5



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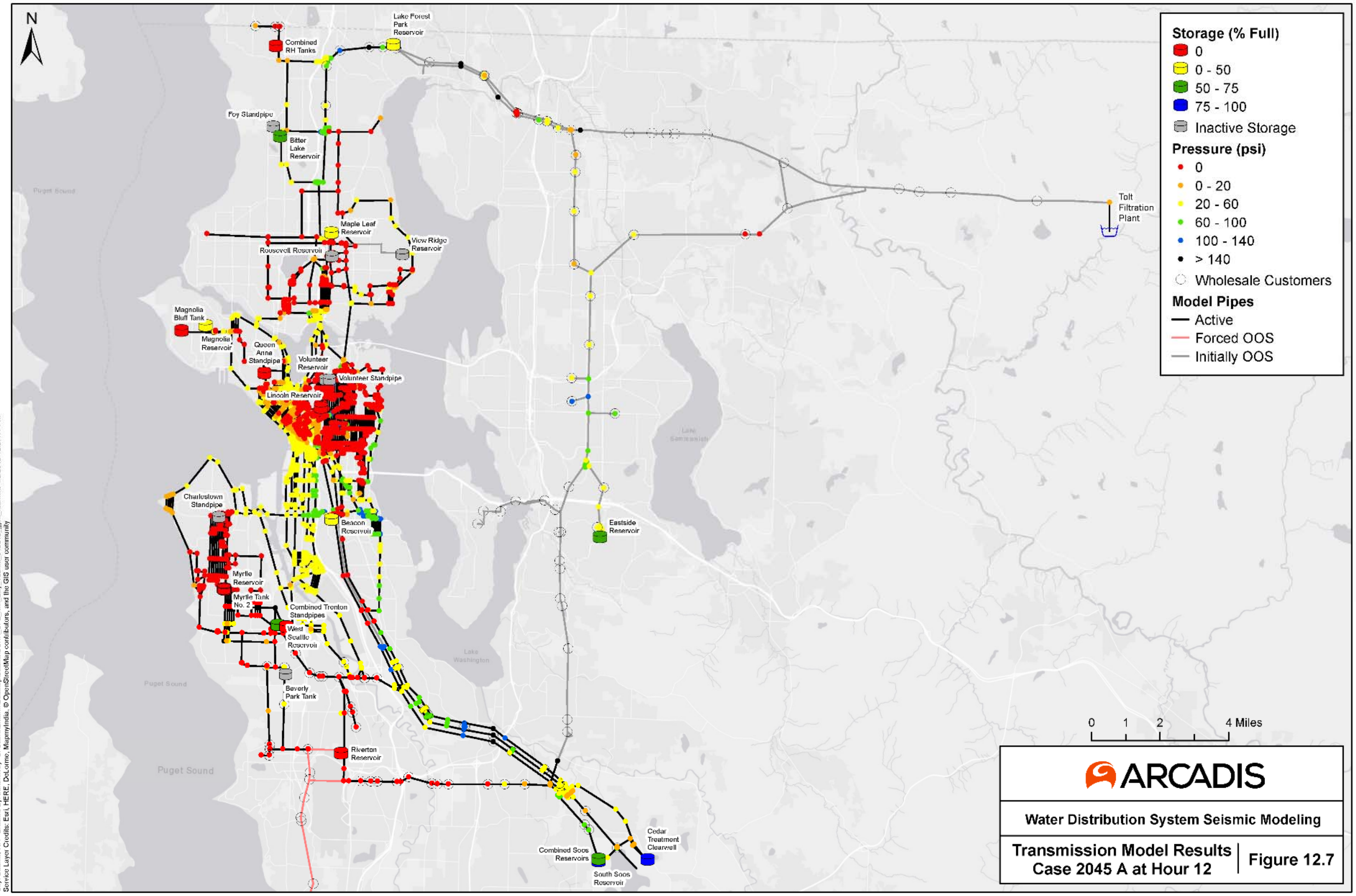

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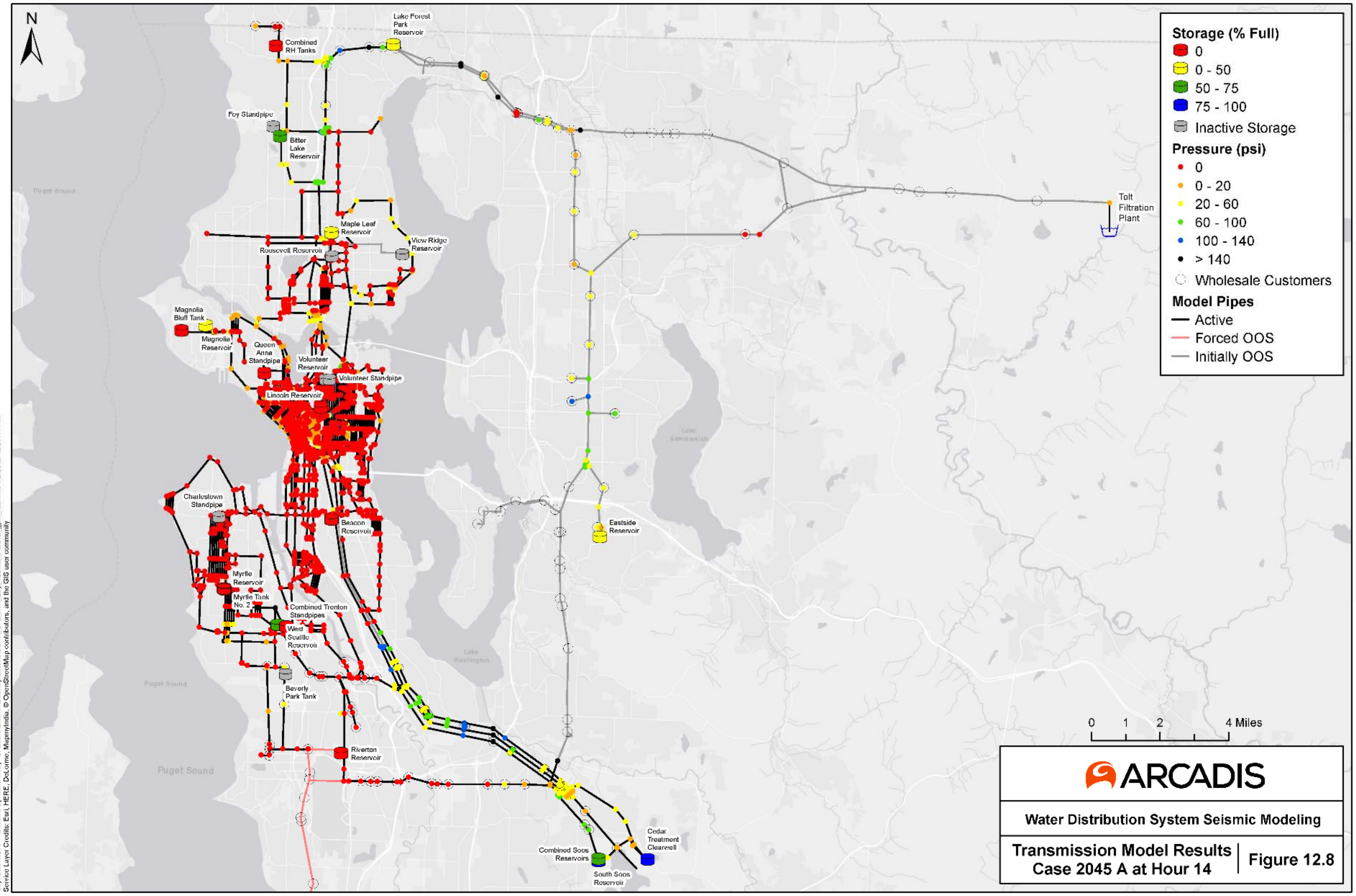
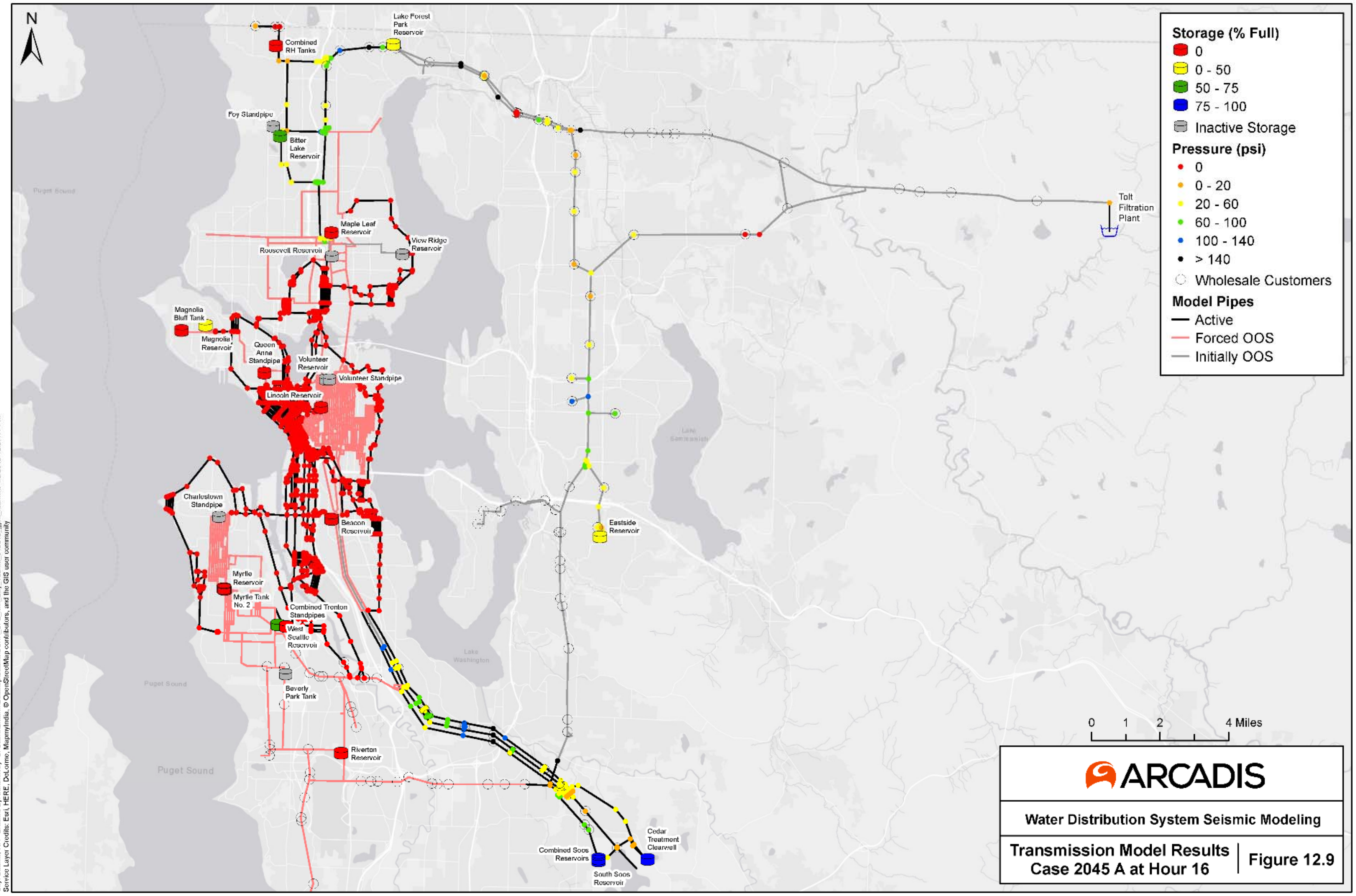

N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Cedar Treatment Clearwell
Combined Soos Reservoirs
South Soos Reservoir
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 14
Figure 12.8



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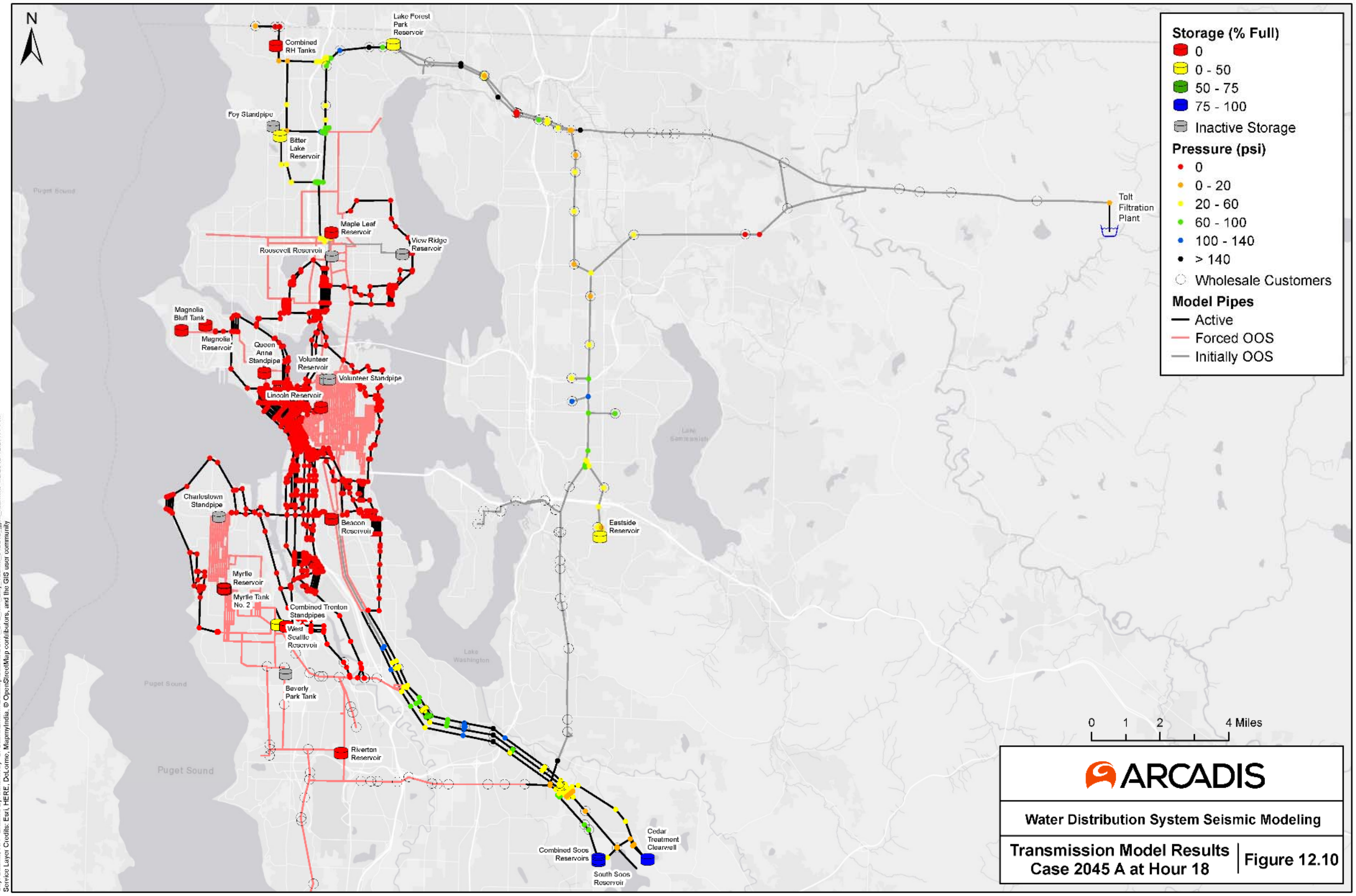
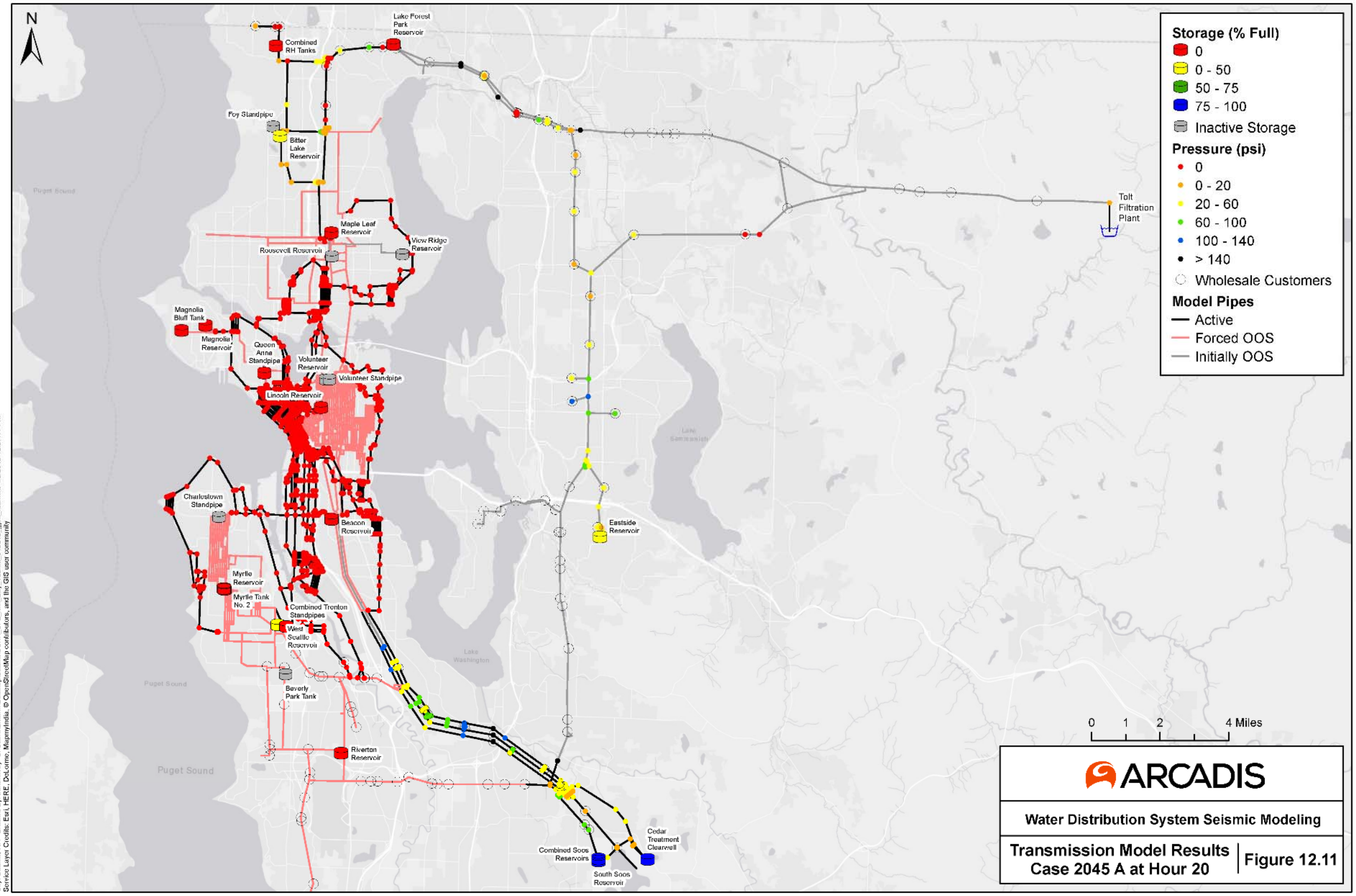


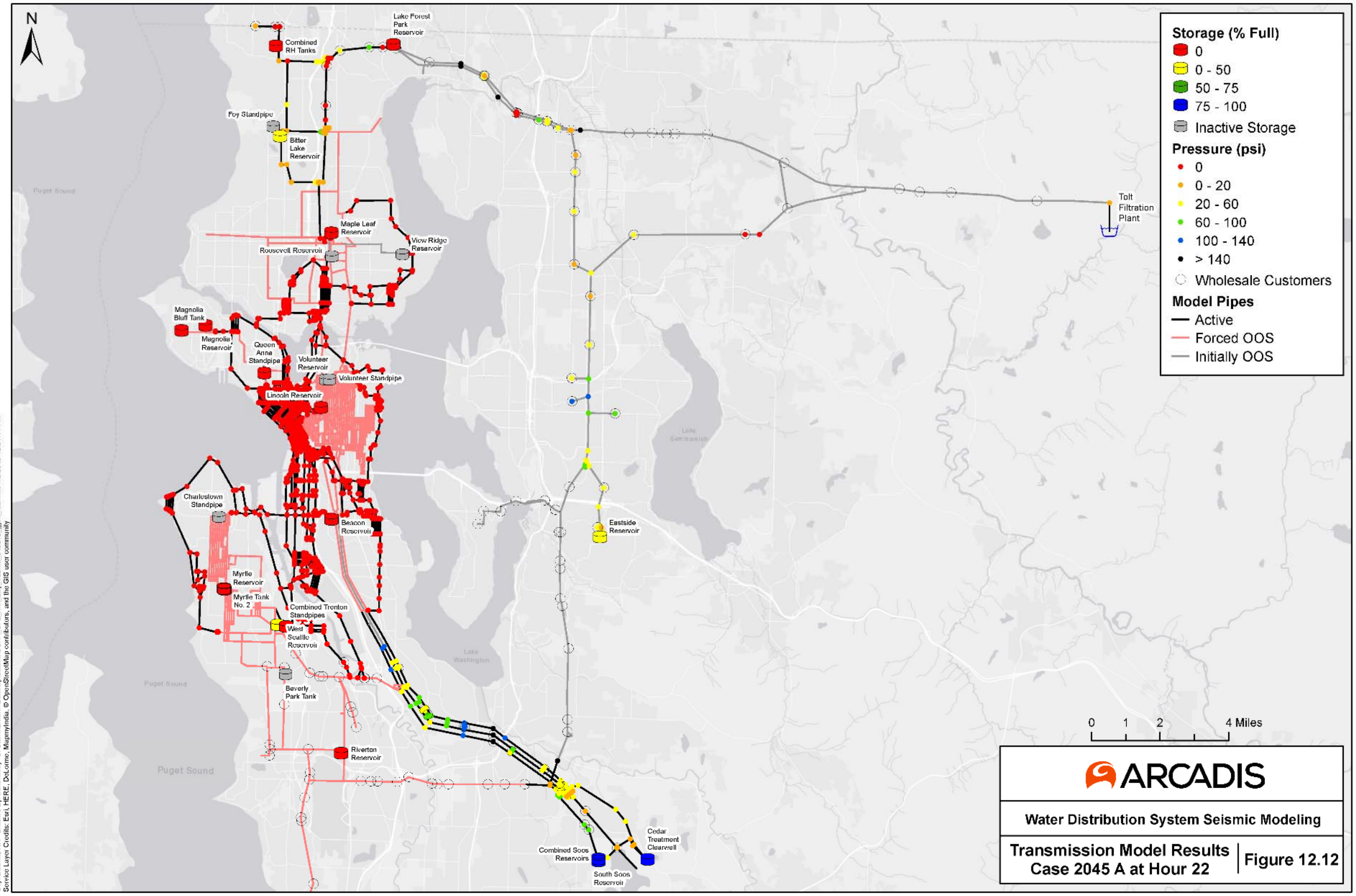
Water Distribution System Seismic Modeling

Transmission Model Results Case 2045 A at Hour 18

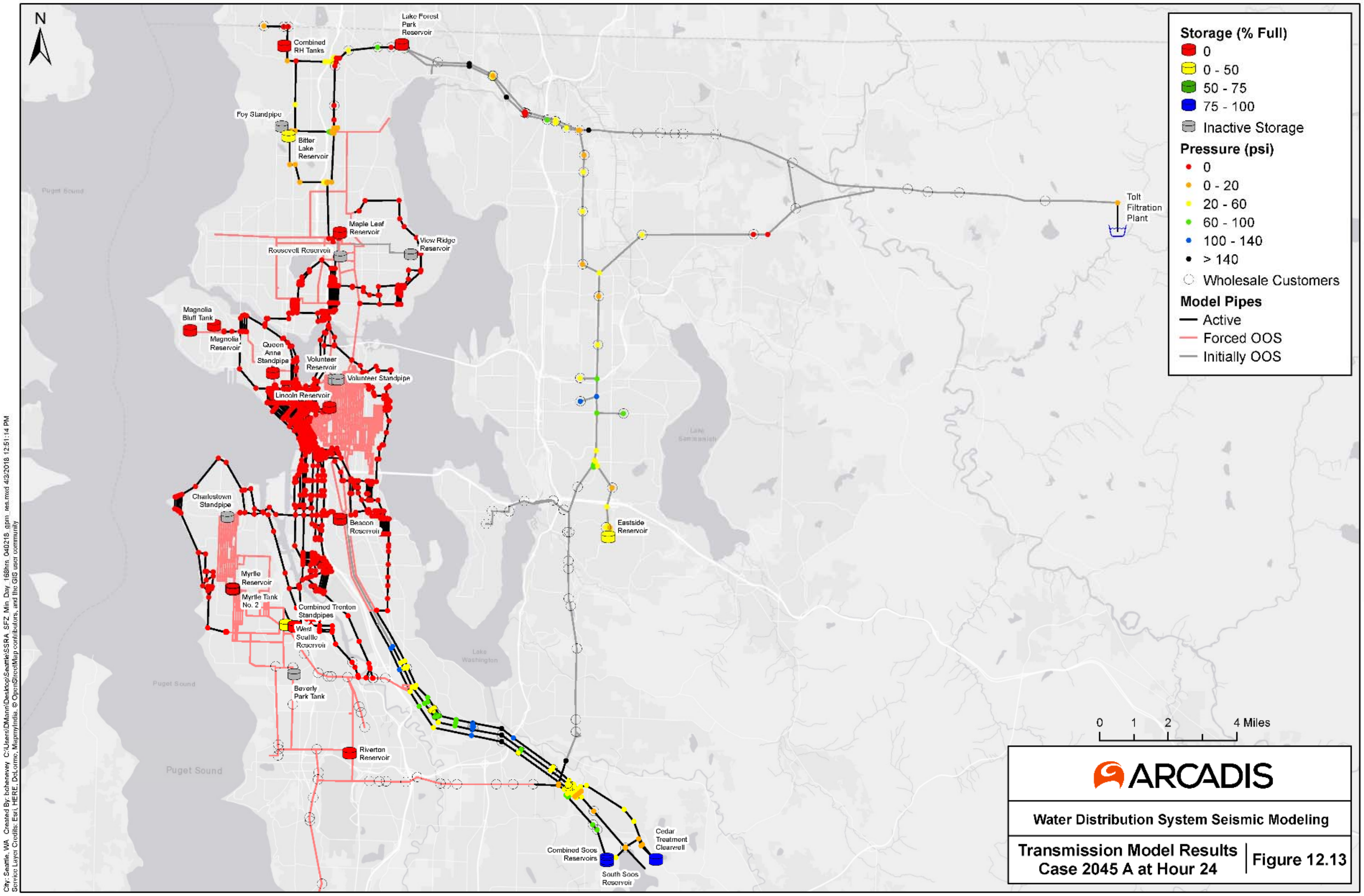
Figure 12.10



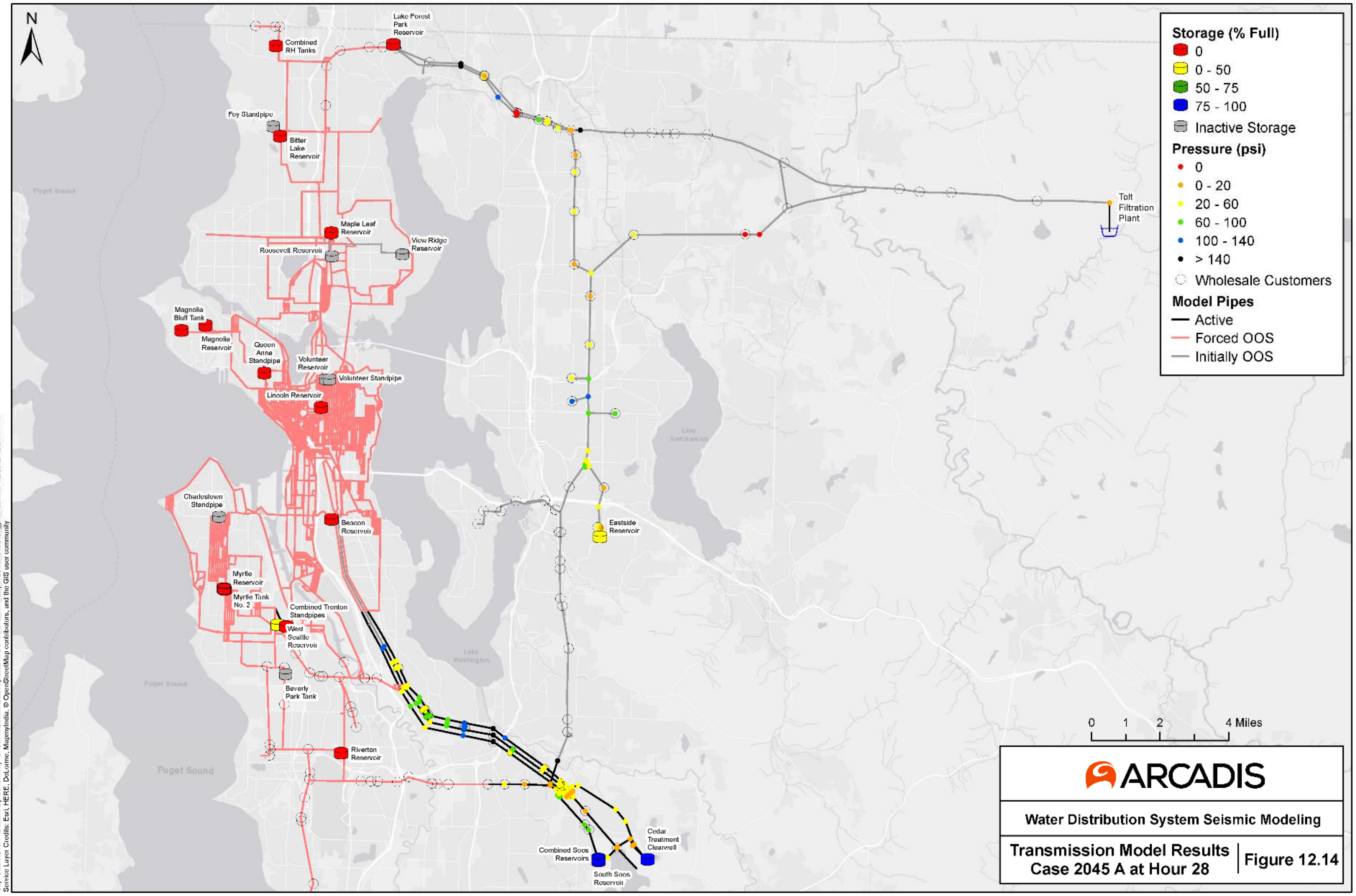
N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 20
Figure 12.11
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish



N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 22
Figure 12.12



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Case 2045 A at Hour 24
Figure 12.13



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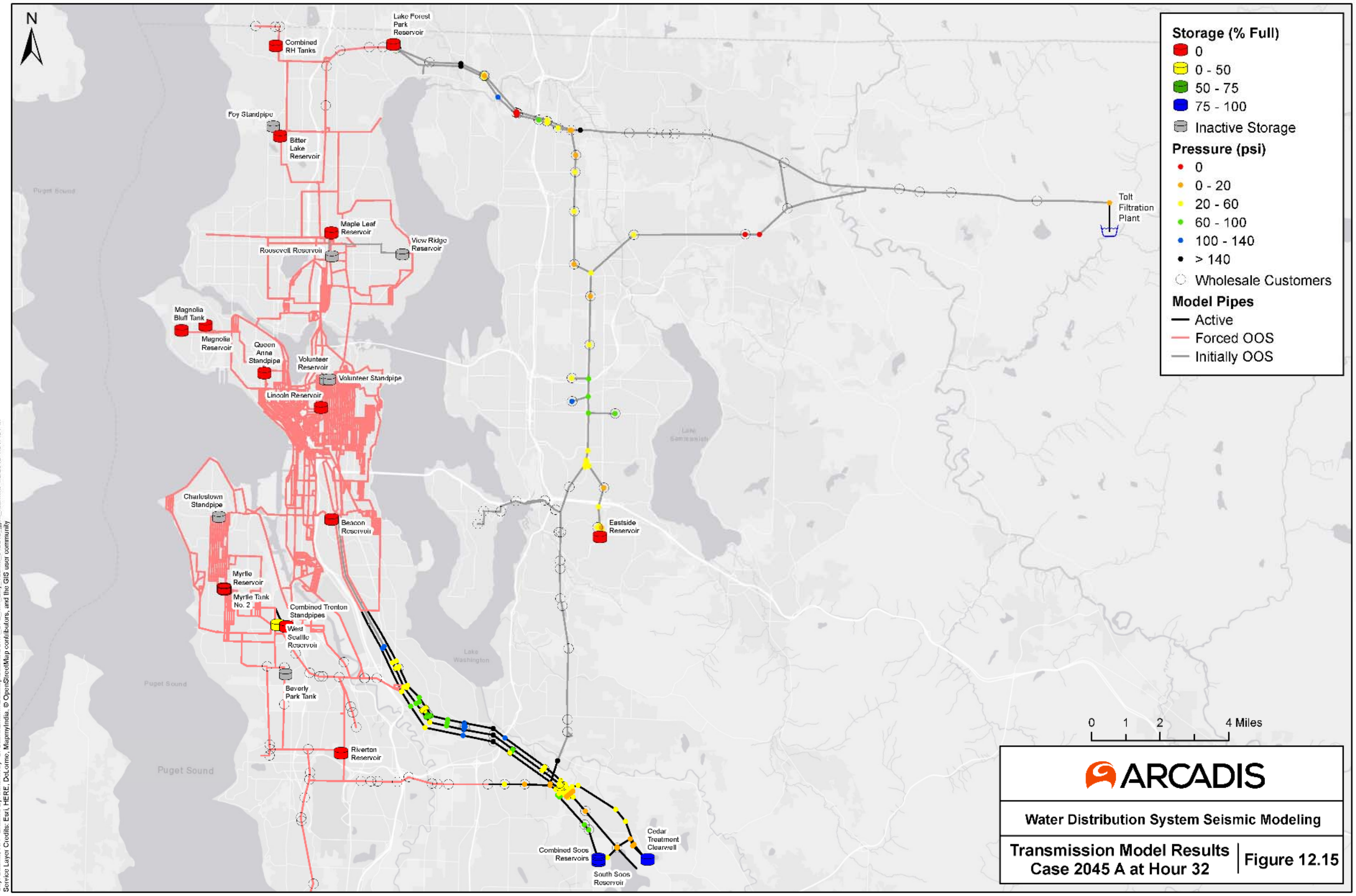
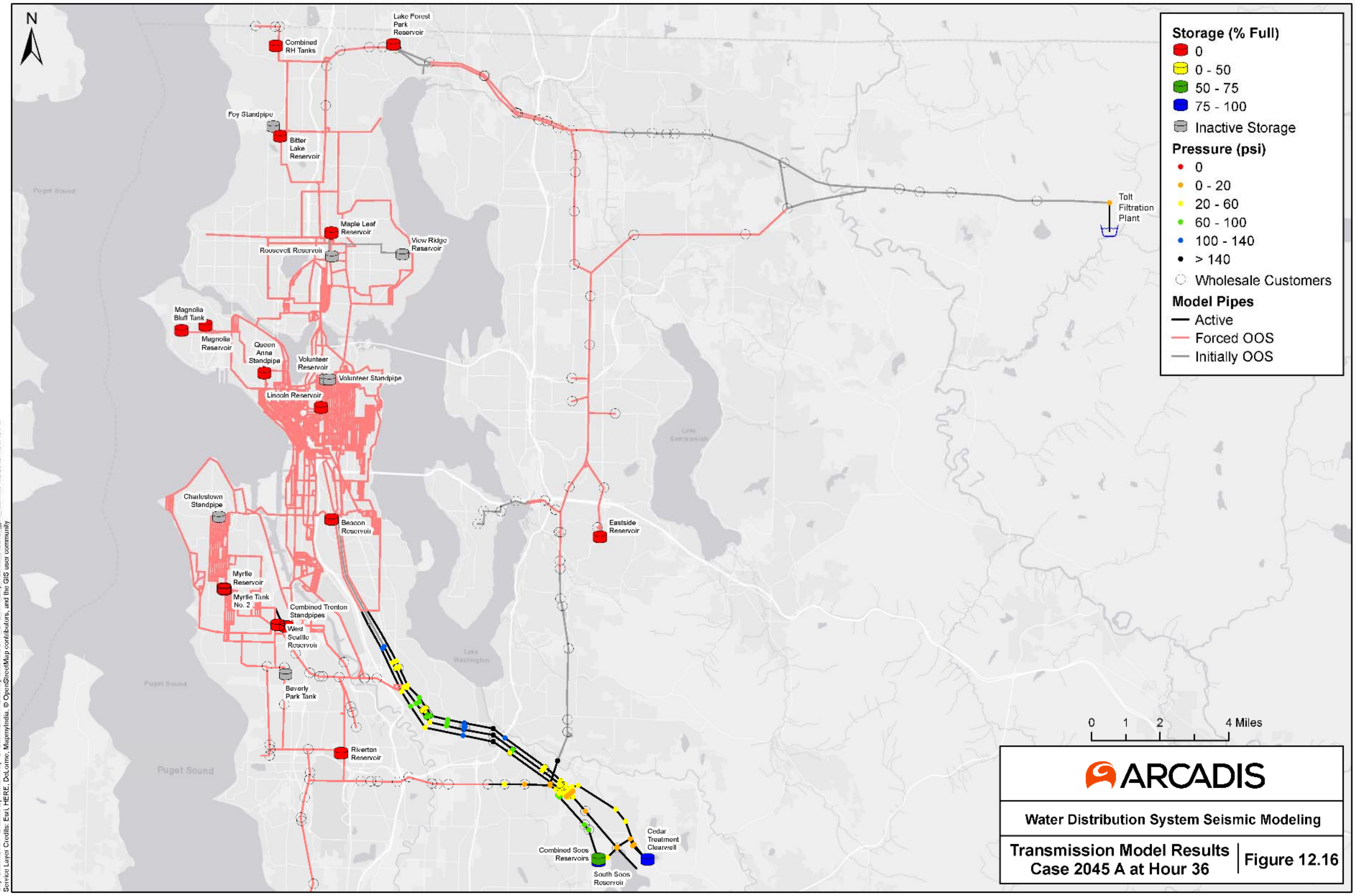
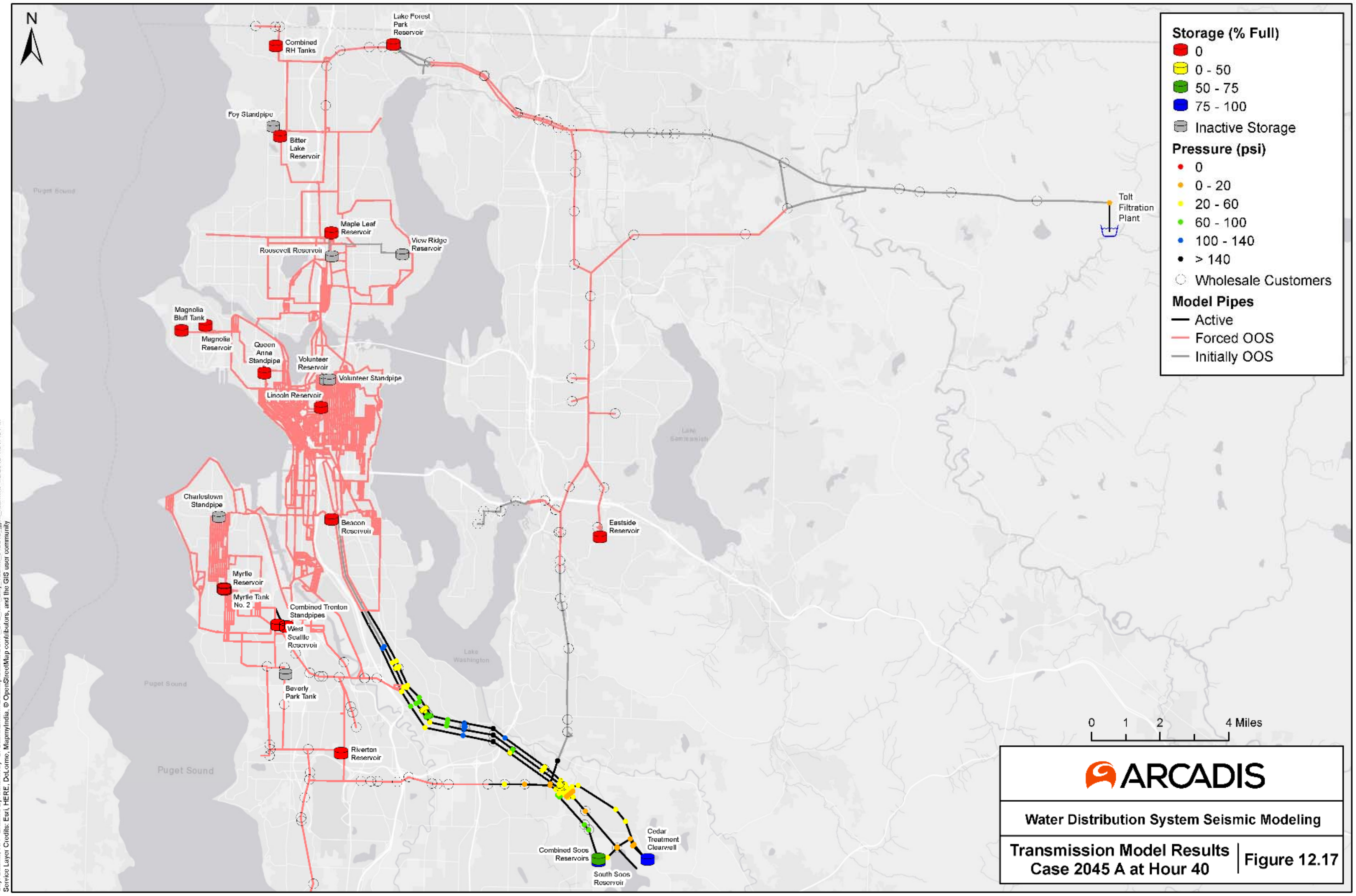
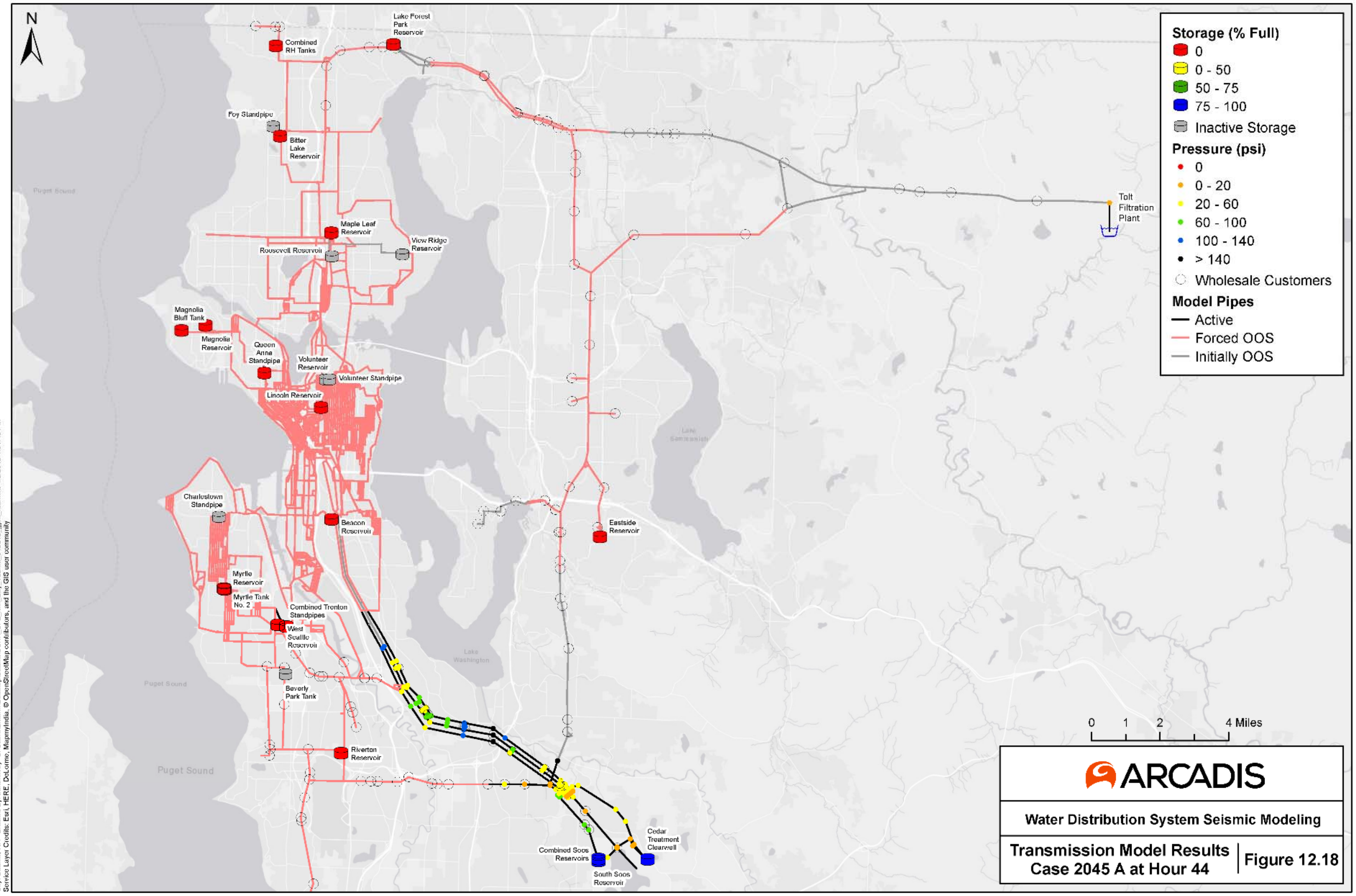

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 32
Figure 12.15

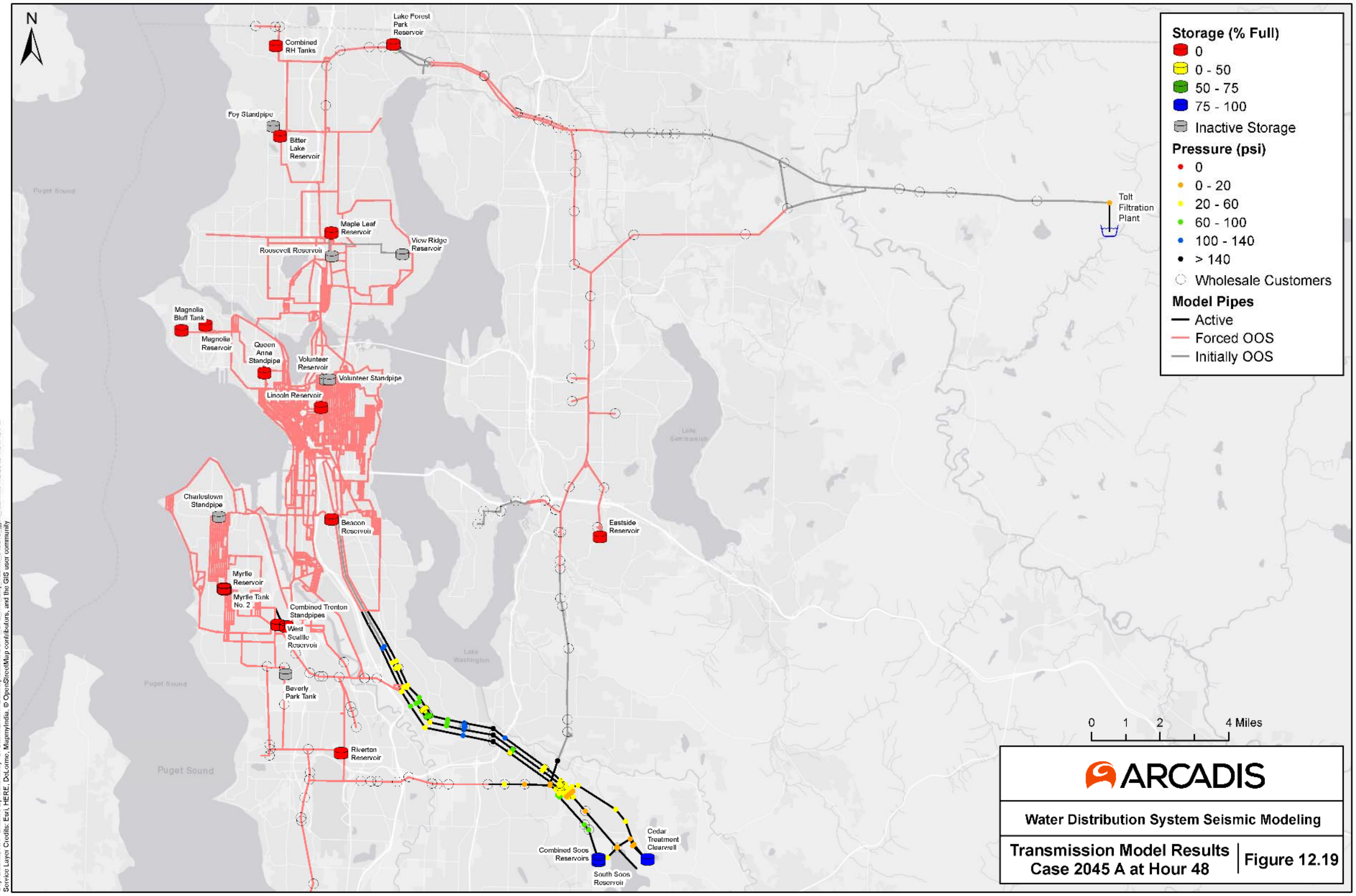


N
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Cedar Treatment Clearwell
Combined Soos Reservoirs
South Soos Reservoir
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 36
Figure 12.16


N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Cedar Treatment Clearwell
Combined Soos Reservoirs
South Soos Reservoir
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 40
Figure 12.17



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 A at Hour 44
Figure 12.18
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Tolt Filtration Plant
Puget Sound
Lake Washington
Lake Sammamish



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M7.0 Seattle Fault Zone Transmission Pipeline Year 2045 Improvement Case with Roosevelt and Volunteer Reservoirs Online Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling
4/4/2018

Seattle Fault Seismic Event
Transmission Pipeline Simulations

Case 2045 B Water from Tolt Filtration Plant cannot be conveyed west;
Eastside Supply Line is open; Tolt Eastside Pipes 7623, 7113, 7079, 7509 are closed;
Facility upgrades are the same as distribution system Case 3 (Volunteer and Roosevelt Reservoirs are) online;
Water from Control Works (Cedar System) cannot be conveyed into the distibution system.

Model Results

Time (hrs)	Total System Demand (gpm)	Emitter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	359,447	299,262	60,184	80%	352.9
3	324,619	268,614	56,005	77%	292.1
12	229,304	186,517	42,788	54%	146.1
22	81,487	52,044	29,443	25%	53.3
32	62,803	39,601	23,202	9%	15.2
48	24,771	17,638	7,133	6%	11.6

Model Regions Forced Out of Service During Simulation

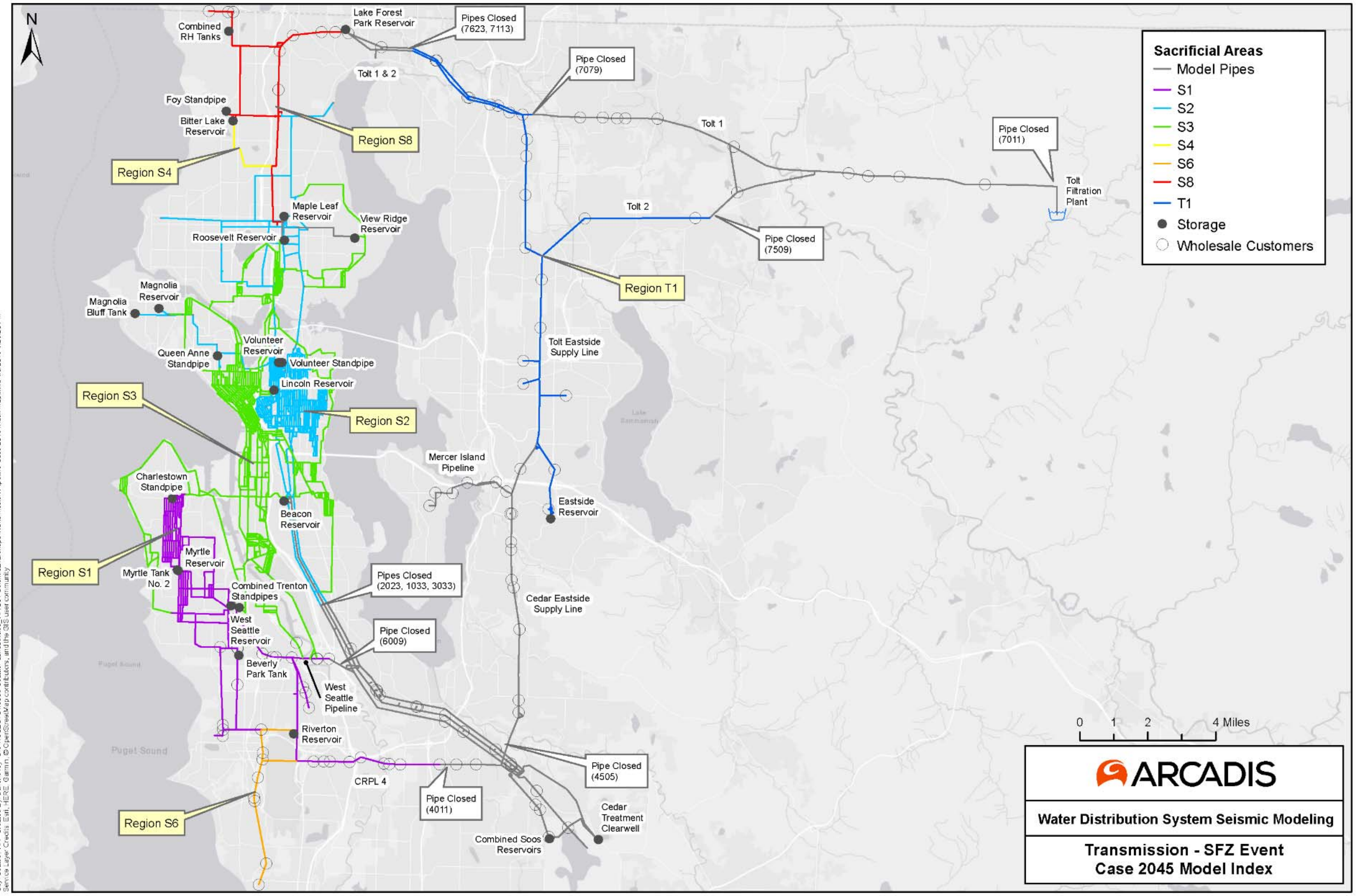
Time	Region
9	S6
15	S1
20	S2
26	S8
32	S3
32	S4
33	T1

Model Simulation Notes

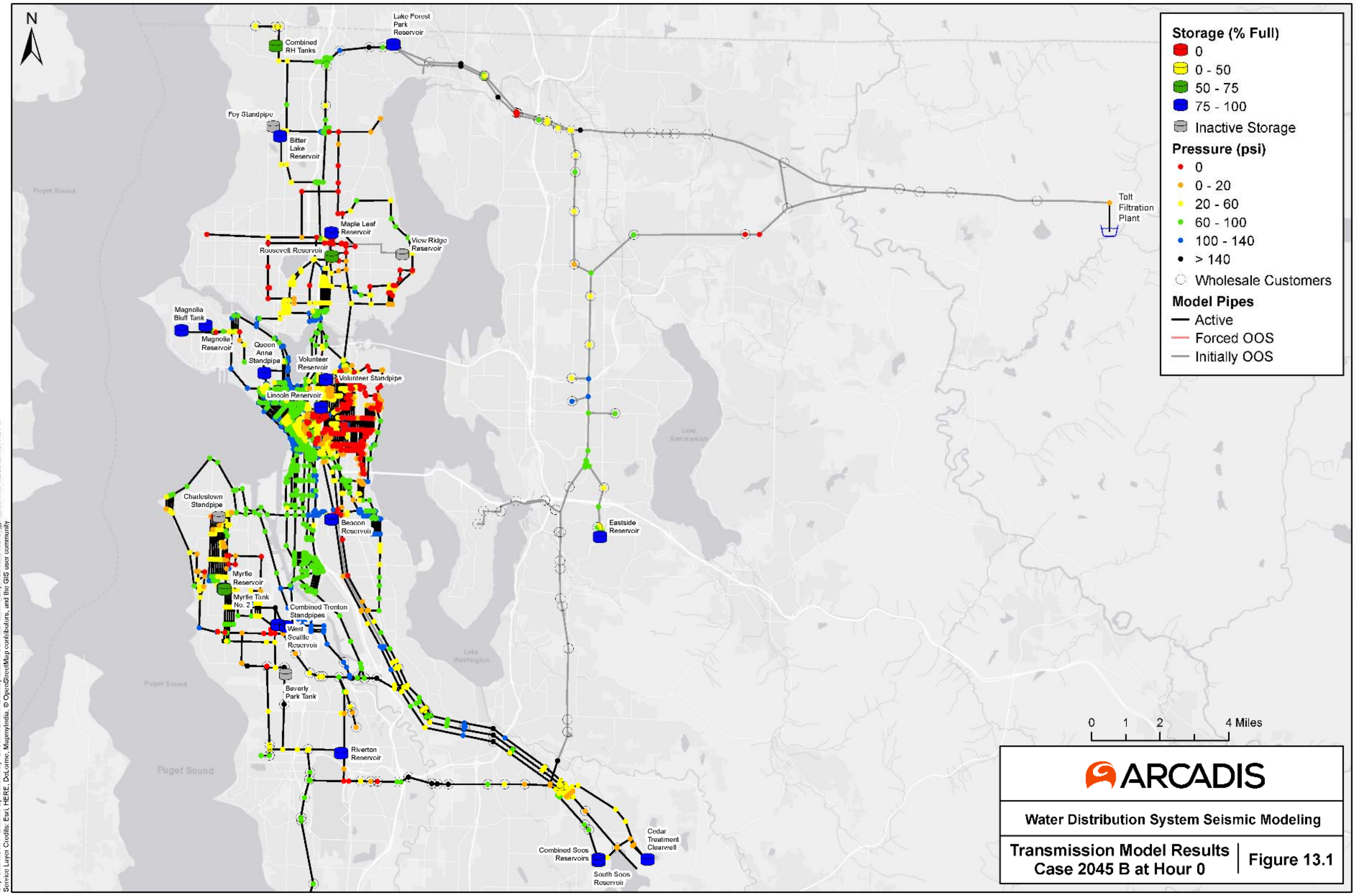
1. *All wholesale customers assumed to start with 1.8 multiplier (max day demands)*
2. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
3. *Total Model Demands with elevated wholesale customers is 91,957 gpm*
4. *Satisfied Demands assume junction pressure greater than 0 psi*
5. *System Positive Pressure based on number of junctions above 0 psi out of the entire model*

Model Results Figure Index

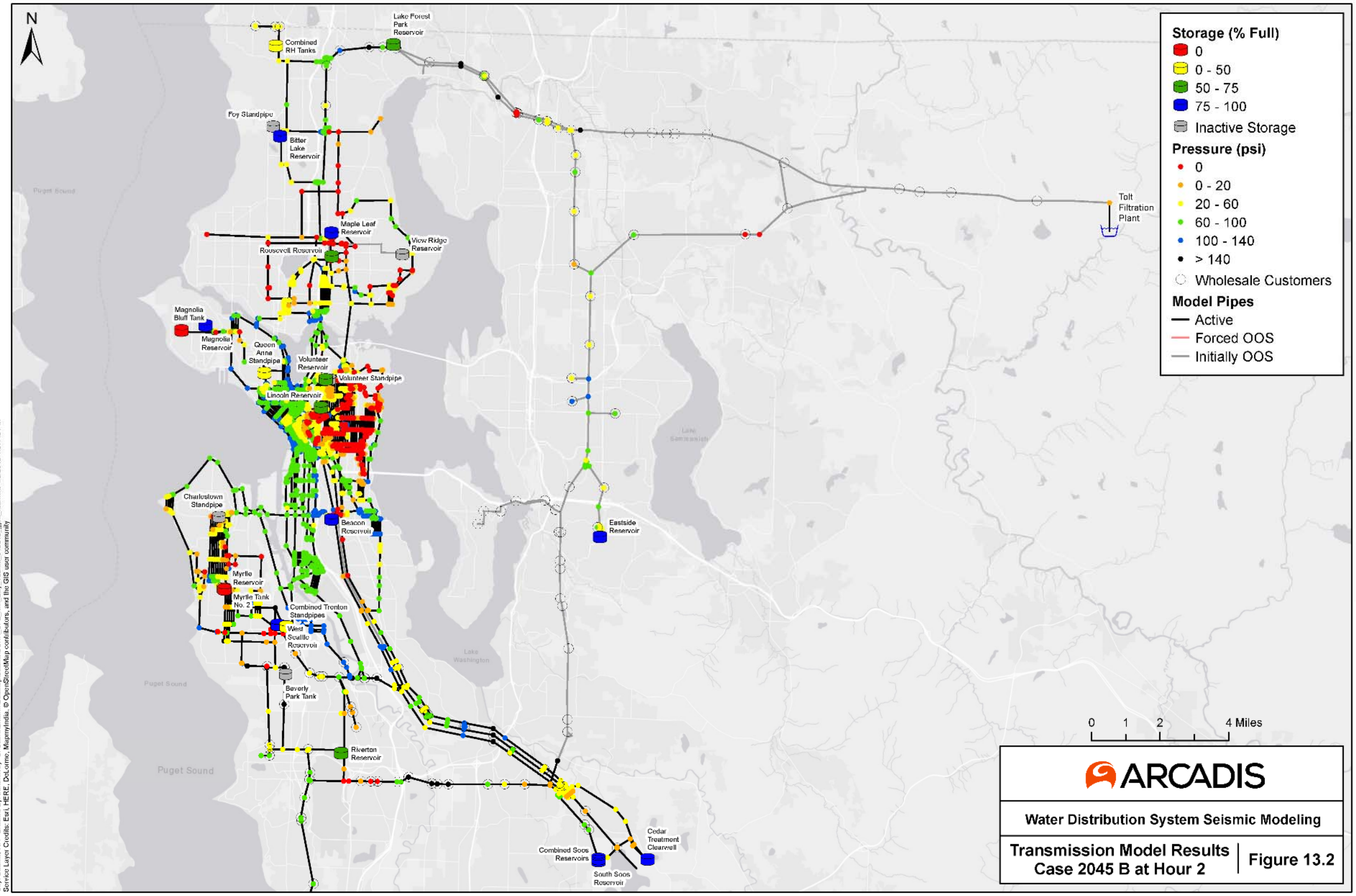
Fig. 13.1	Hr 0	Fig. 13.5	Hr 8	Fig. 13.9	Hr 16	Fig. 13.13	Hr 24	Fig. 13.17	Hr 40
Fig. 13.2	Hr 2	Fig. 13.6	Hr 10	Fig. 13.10	Hr 18	Fig. 13.14	Hr 28	Fig. 13.18	Hr 44
Fig. 13.3	Hr 4	Fig. 13.7	Hr 12	Fig. 13.11	Hr 20	Fig. 13.15	Hr 32	Fig. 13.19	Hr 48
Fig. 13.4	Hr 6	Fig. 13.8	Hr 14	Fig. 13.12	Hr 22	Fig. 13.16	Hr 36		



N
Sacrificial Areas
Model Pipes
S1
S2
S3
S4
S6
S8
T1
Storage
Wholesale Customers
Combined RH Tanks
Lake Forest Park Reservoir
Pipes Closed (7623, 7113)
Tolt 1 & 2
Pipe Closed (7079)
Foy Standpipe
Bitter Lake Reservoir
Region S8
Region S4
Tolt 1
Pipe Closed (7011)
Tolt Filtration Plant
Tolt 2
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Pipe Closed (7509)
Region T1
Magnolia Reservoir
Magnolia Bluff Tank
Volunteer Reservoir
Queen Anne Standpipe
Volunteer Standpipe
Tolt Eastside Supply Line
Lincoln Reservoir
Region S3
Region S2
Mercer Island Pipeline
Charlestown Standpipe
Eastside Reservoir
Beacon Reservoir
Myrtle Reservoir
Region S1
Myrtle Tank No. 2
Pipes Closed (2023, 1033, 3033)
Combined Trenton Standpipes
Cedar Eastside Supply Line
West Seattle Reservoir
Pipe Closed (6009)
Beverly Park Tank
West Seattle Pipeline
Puget Sound
Riverton Reservoir
Pipe Closed (4505)
CRPL 4
Pipe Closed (4011)
Region S6
Cedar Treatment Clearwell
Combined Soos Reservoirs
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission - SFZ Event
Case 2045 Model Index



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Case 2045 B at Hour 0
Figure 13.1



ARCADIS

Water Distribution System Seismic Modeling

Transmission Model Results Case 2045 B at Hour 2 | Figure 13.2

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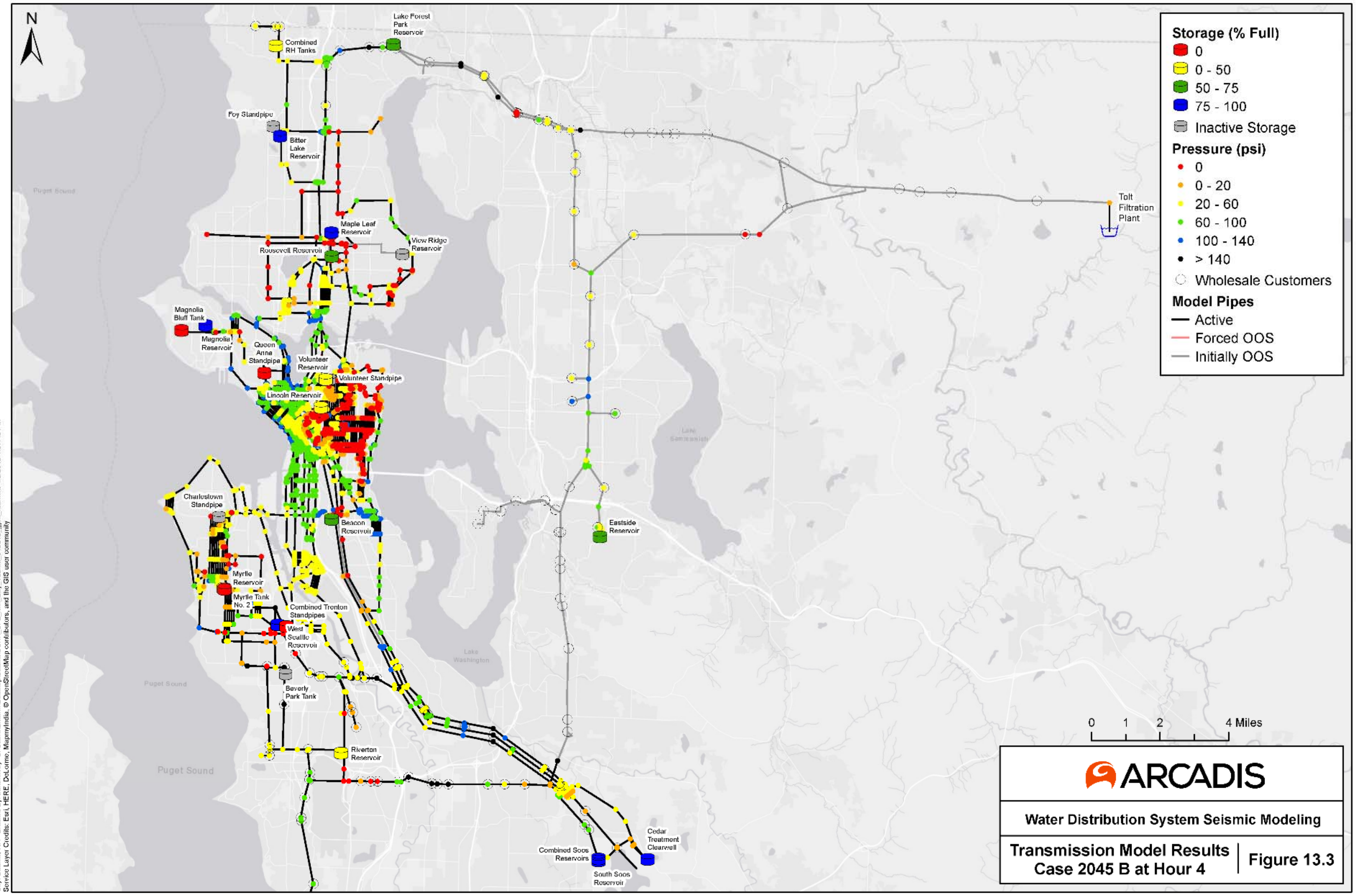
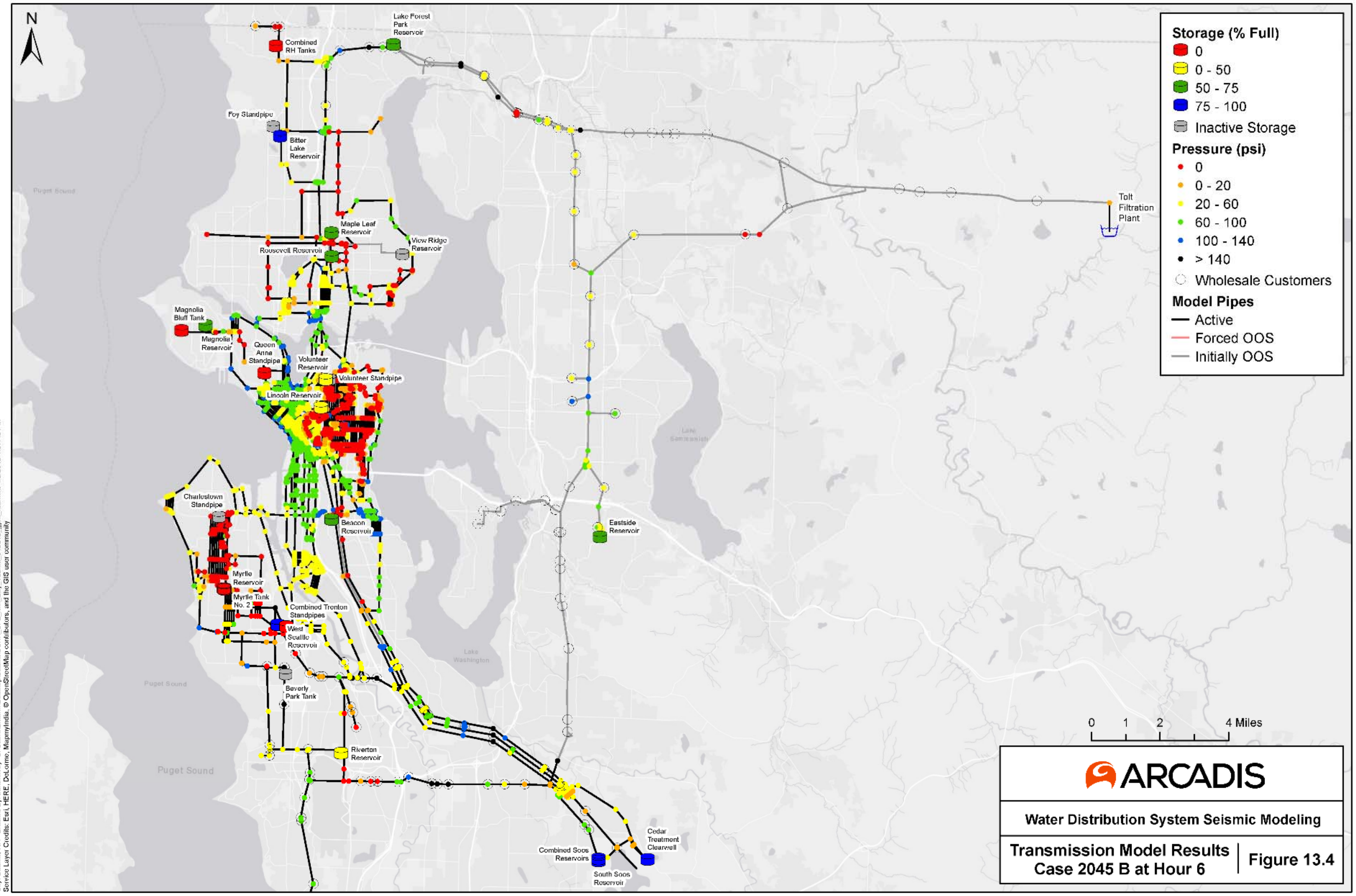
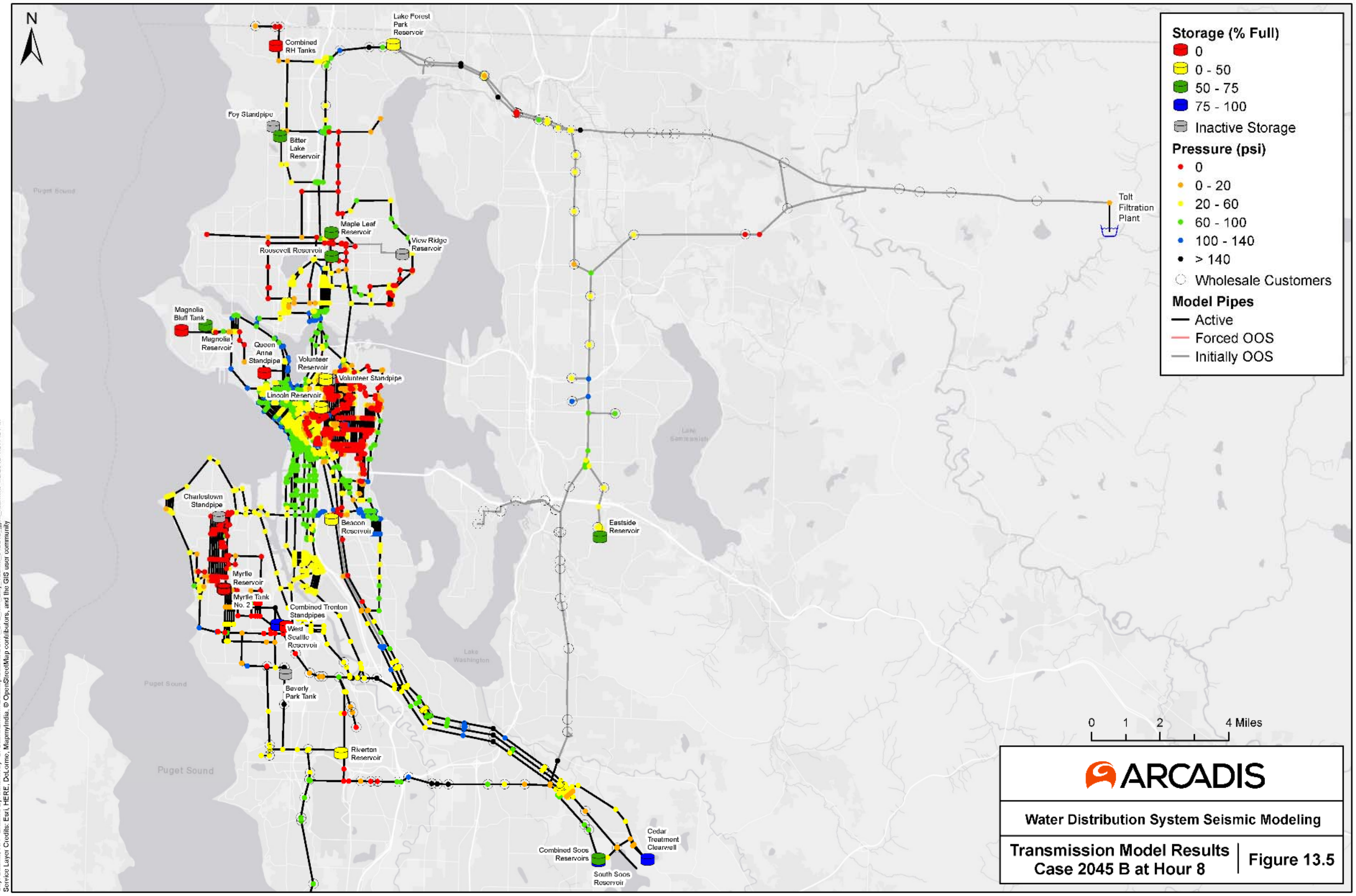

N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Tolt Filtration Plant
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 B at Hour 4
Figure 13.3

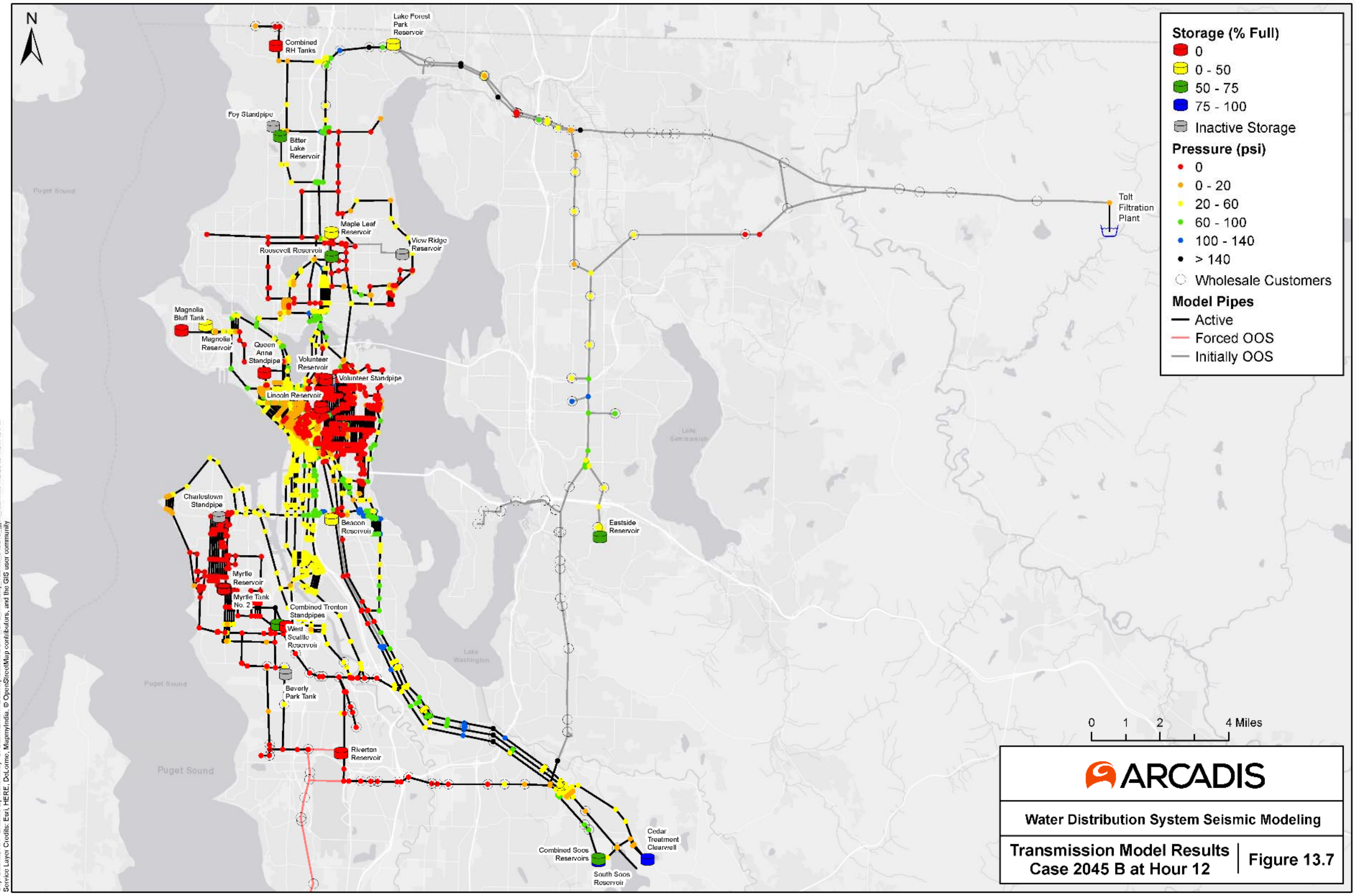


N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Eastside Reservoir
Tolt Filtration Plant
Puget Sound
Lake Washington
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 B at Hour 6
Figure 13.4



Transmission Model Results
Case 2045 B at Hour 8

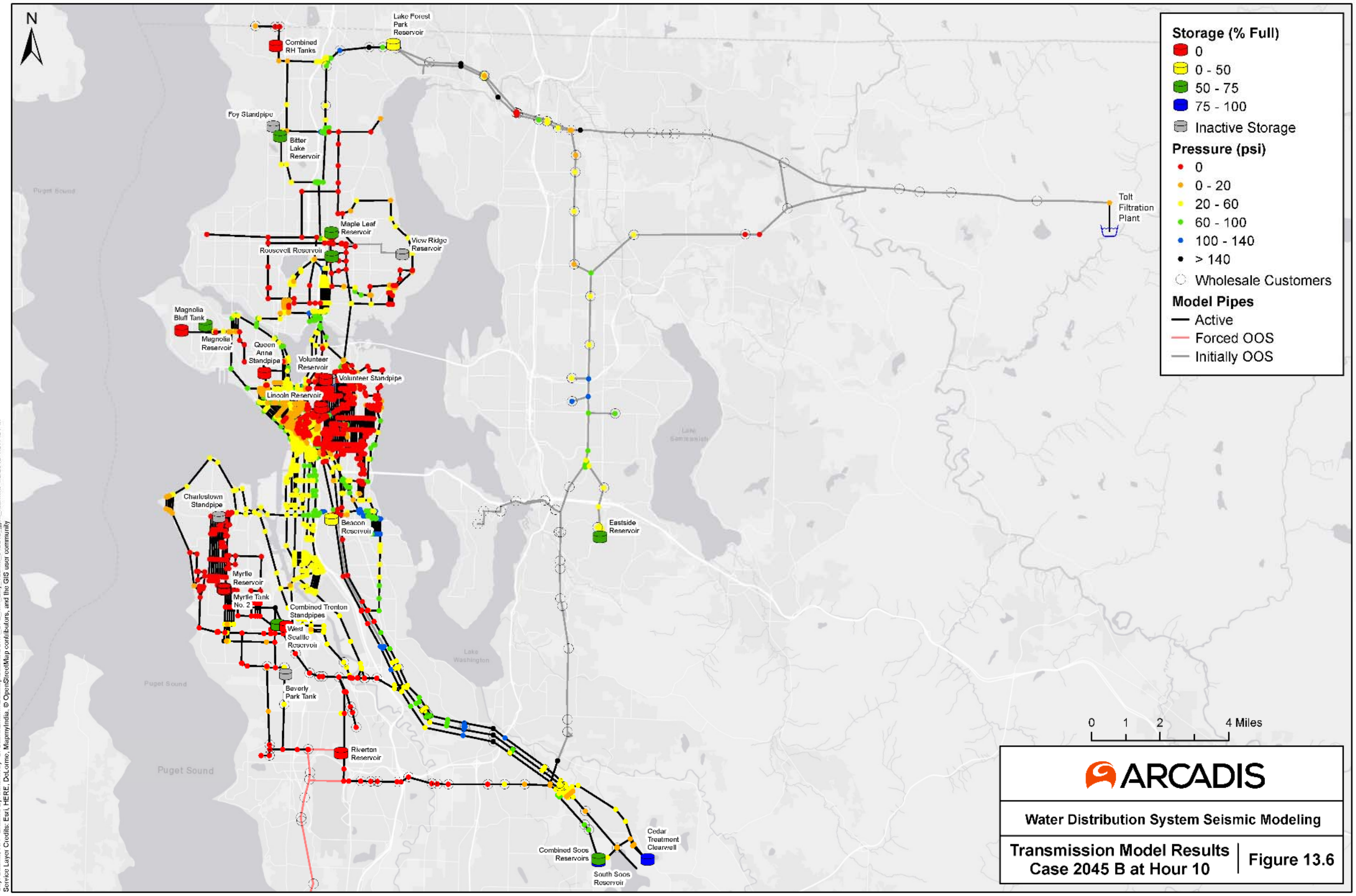
Figure 13.5

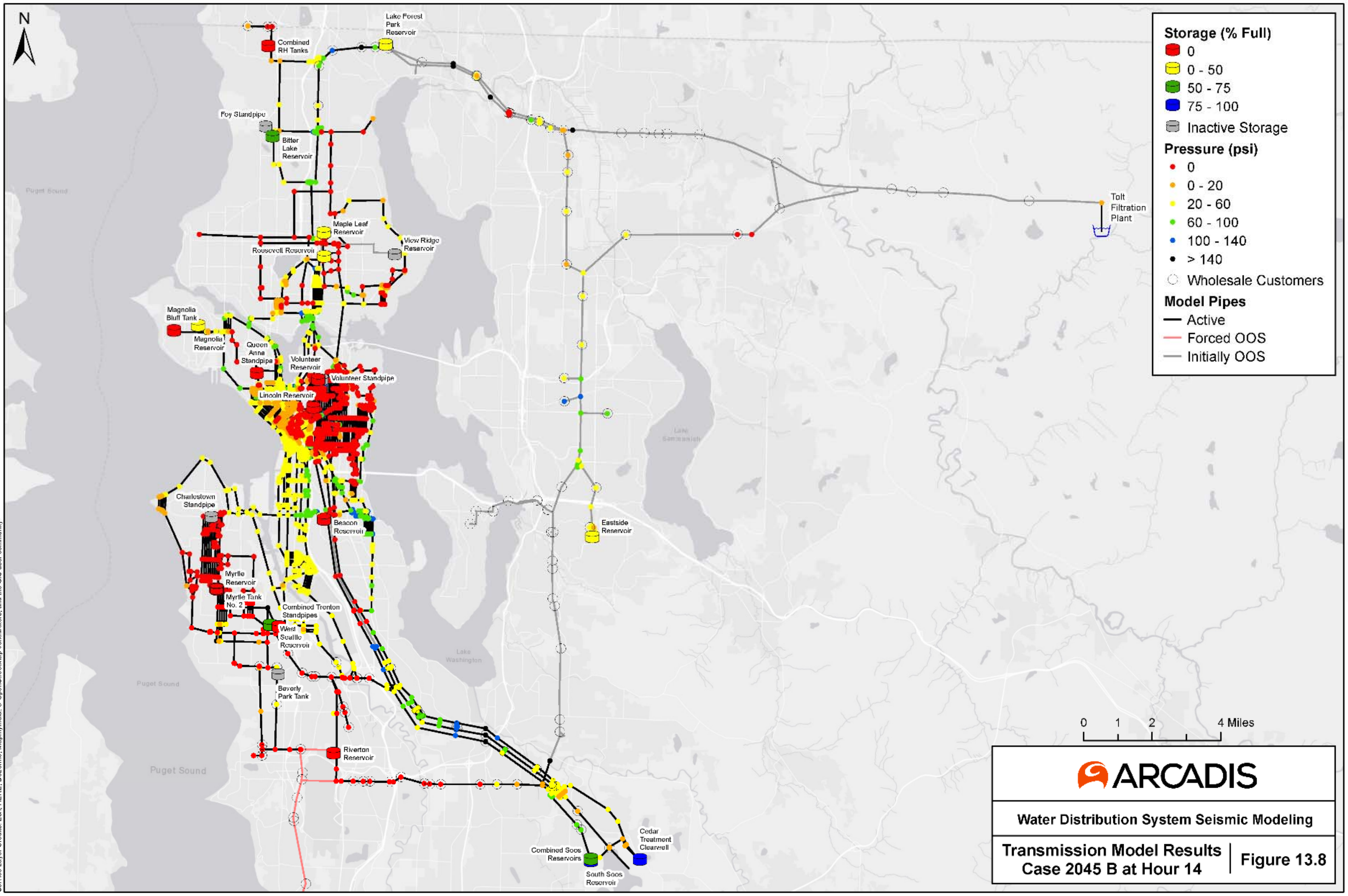


Water Distribution System Seismic Modeling

Transmission Model Results
Case 2045 B at Hour 12

Figure 13.7


N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 B at Hour 10
Figure 13.6
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish

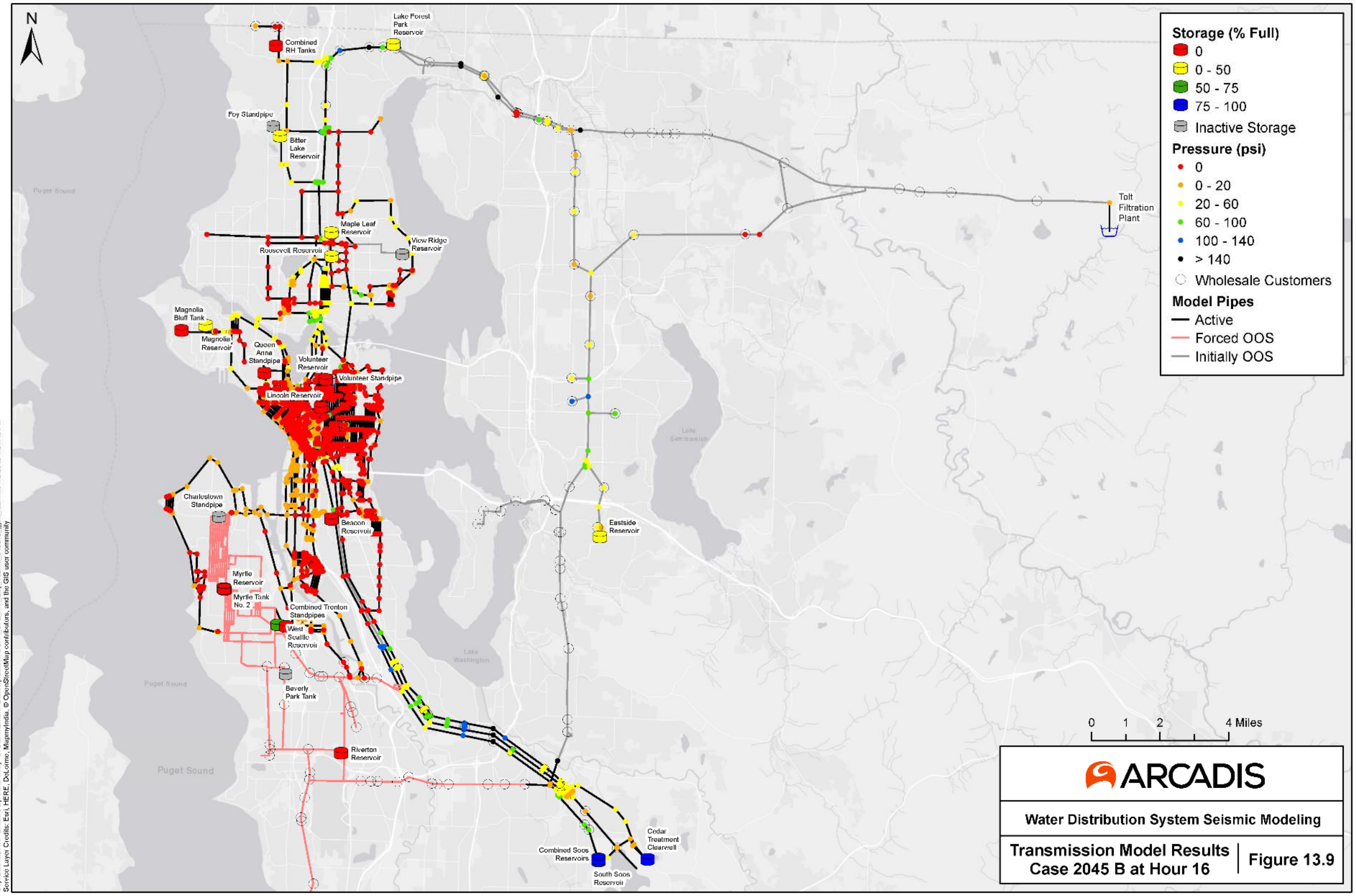


ARCADIS

Water Distribution System Seismic Modeling

Transmission Model Results
Case 2045 B at Hour 14

Figure 13.8



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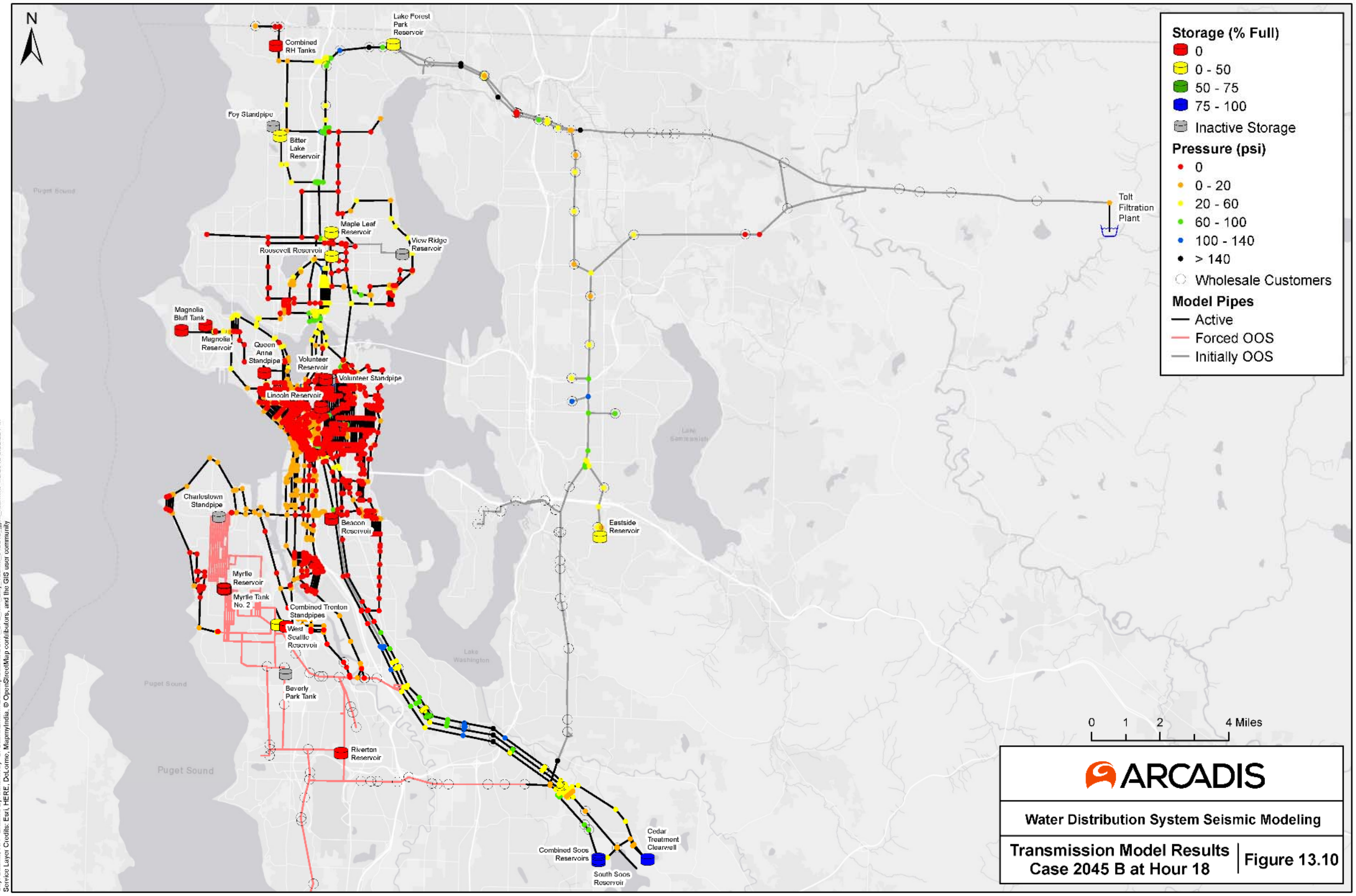
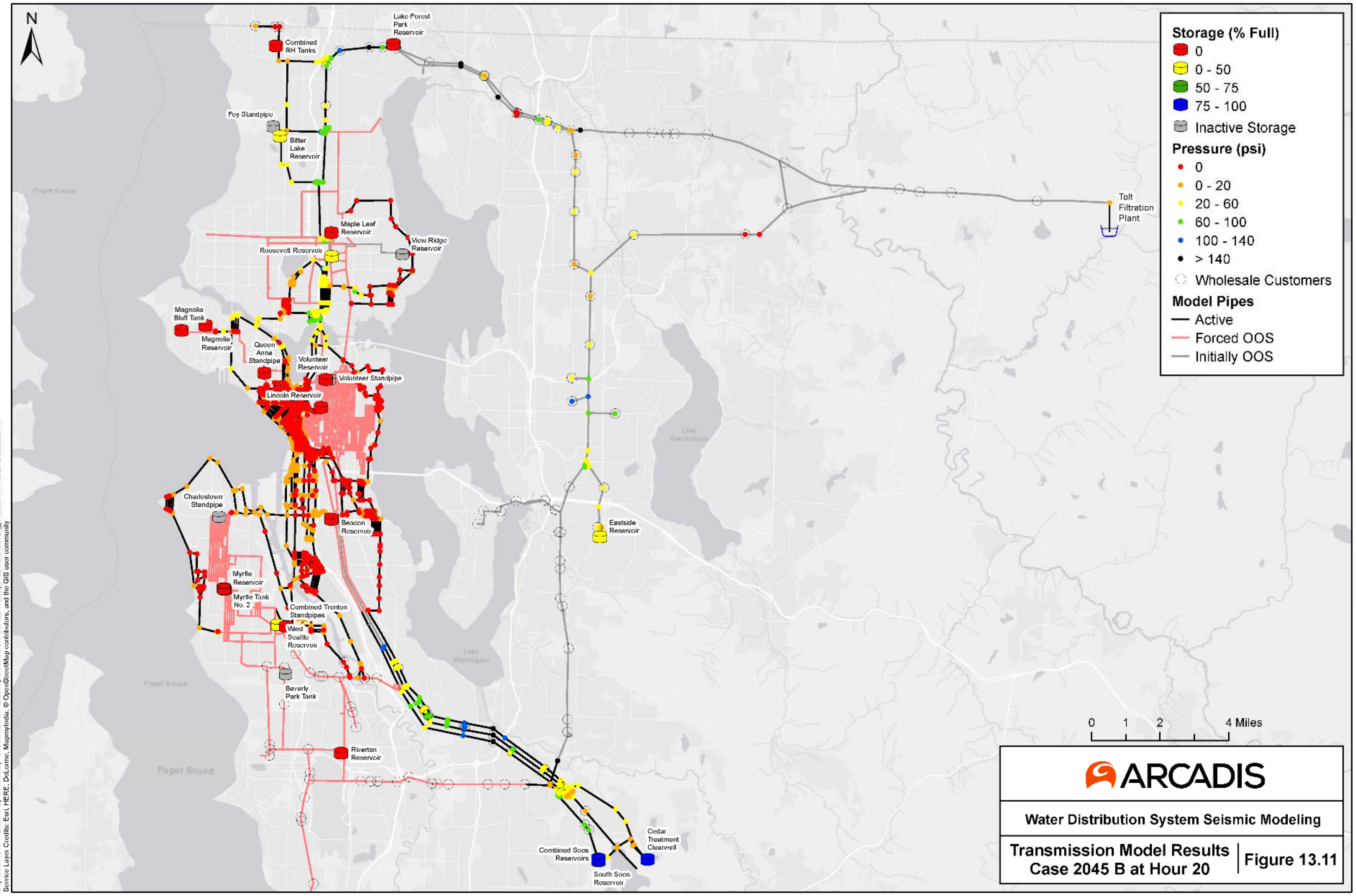


ARCADIS

Water Distribution System Seismic Modeling

Transmission Model Results Case 2045 B at Hour 18

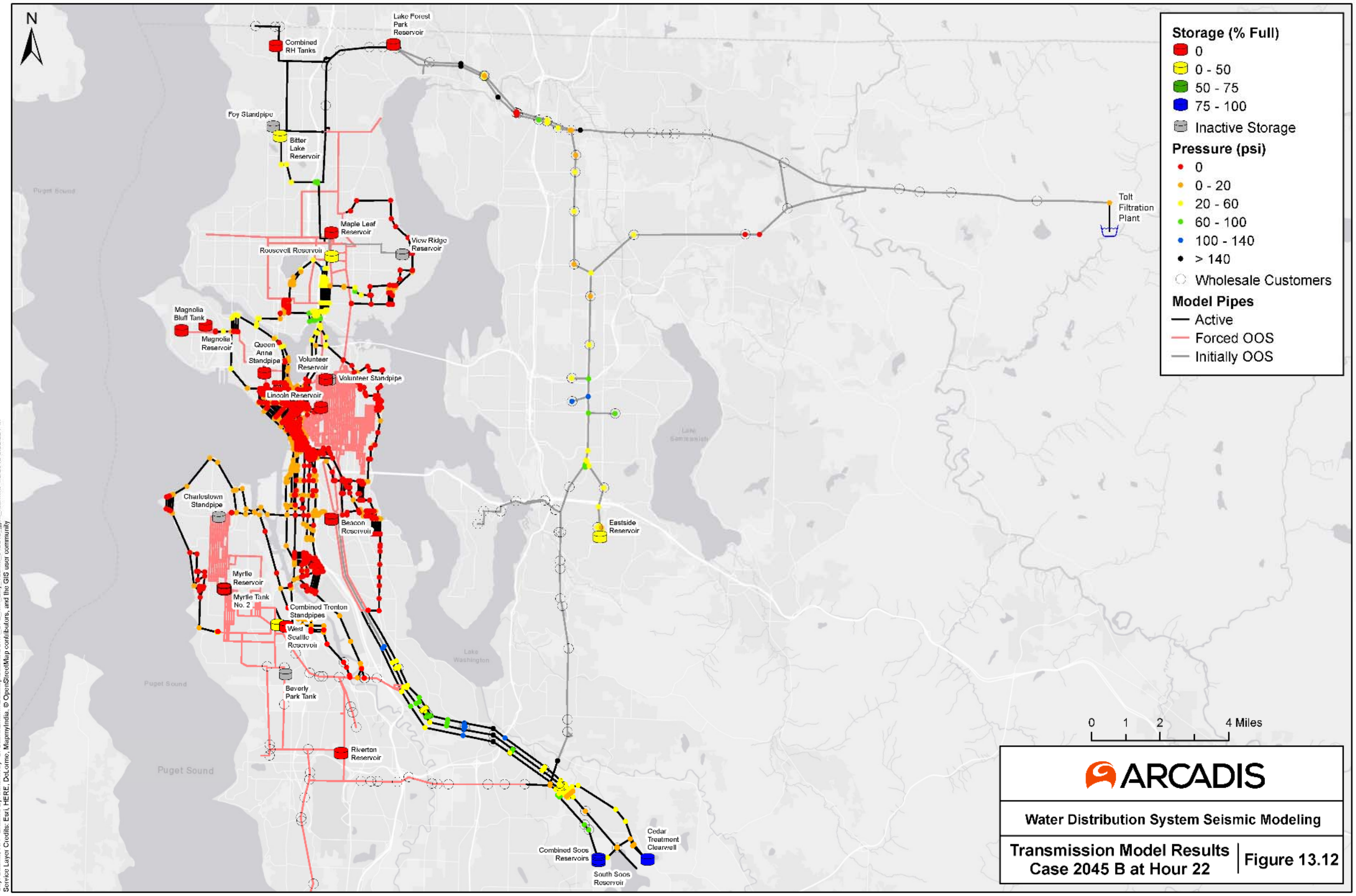
Figure 13.10



Water Distribution System Seismic Modeling

Transmission Model Results Case 2045 B at Hour 20

Figure 13.11


N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
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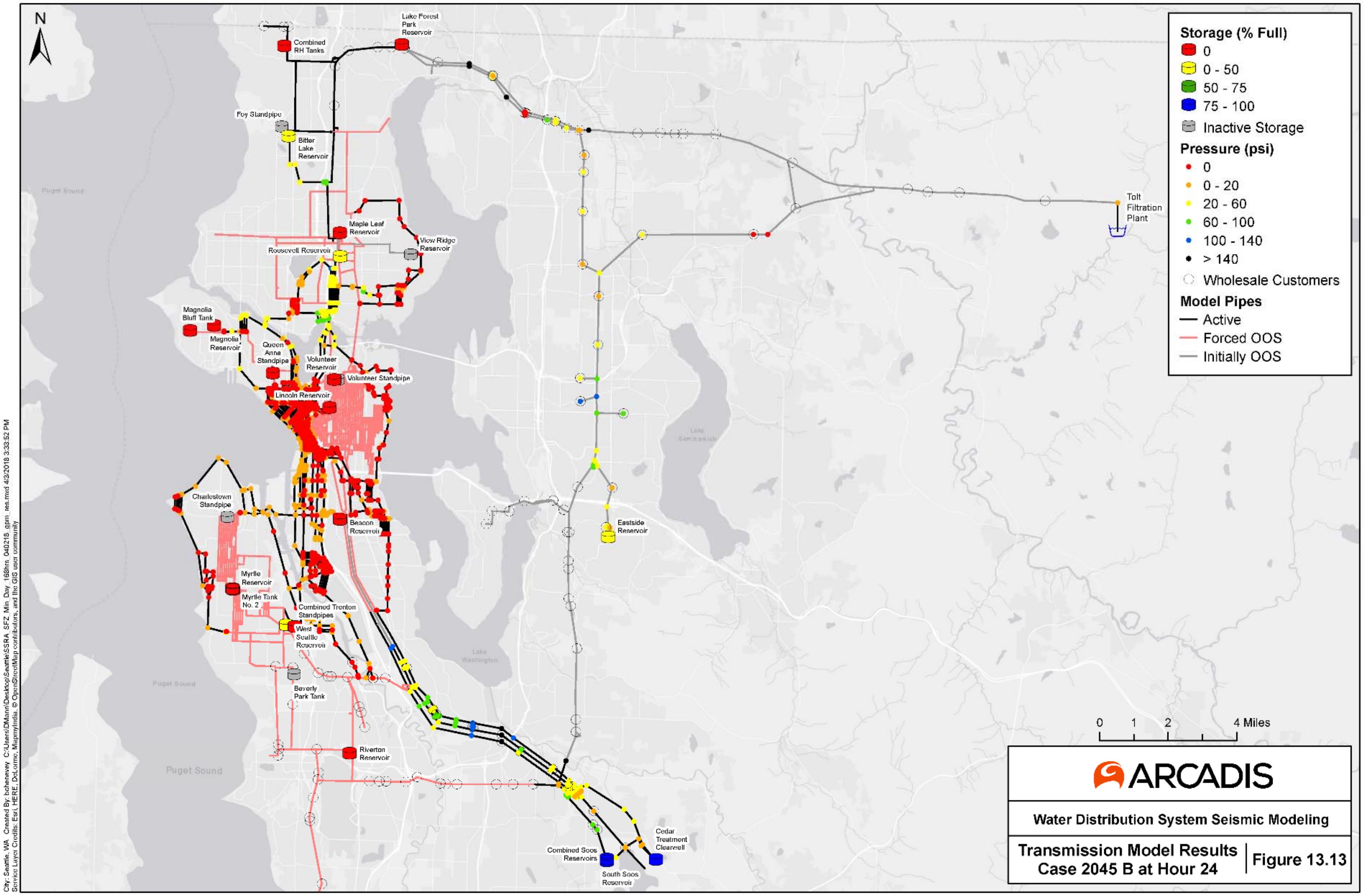
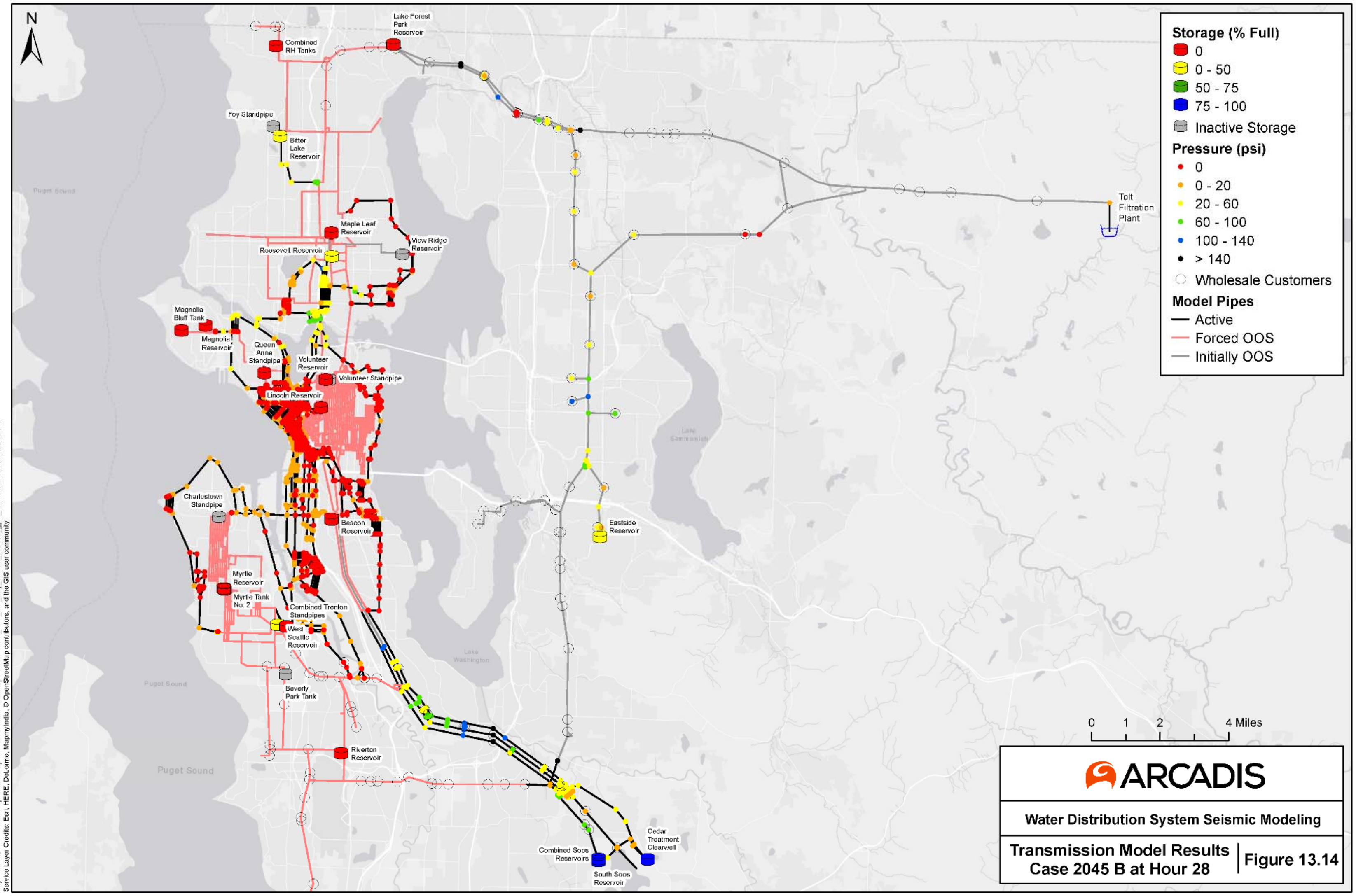
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2045 B at Hour 22
Figure 13.12



Transmission Model Results
Case 2045 B at Hour 24
Figure 13.13



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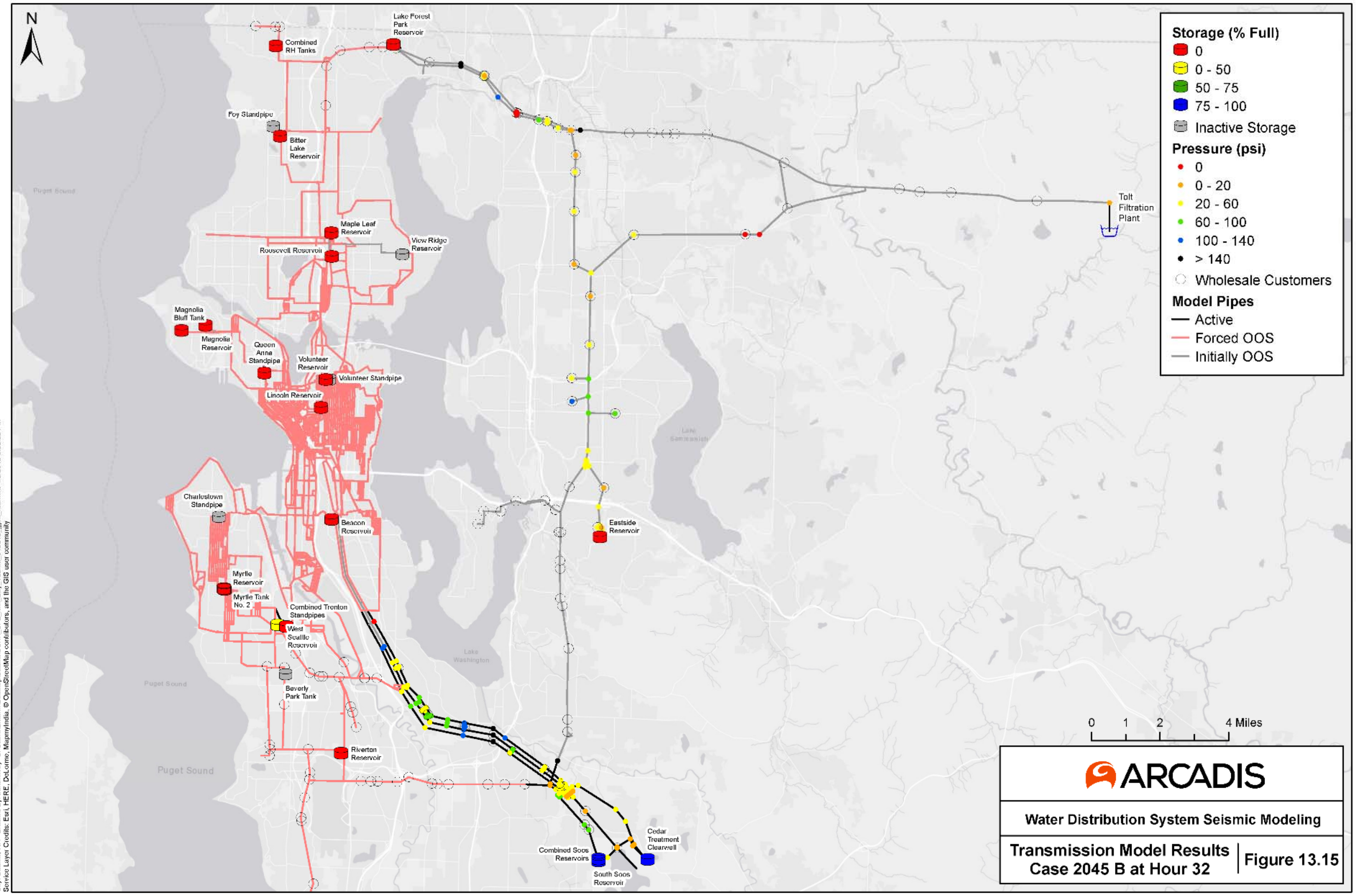
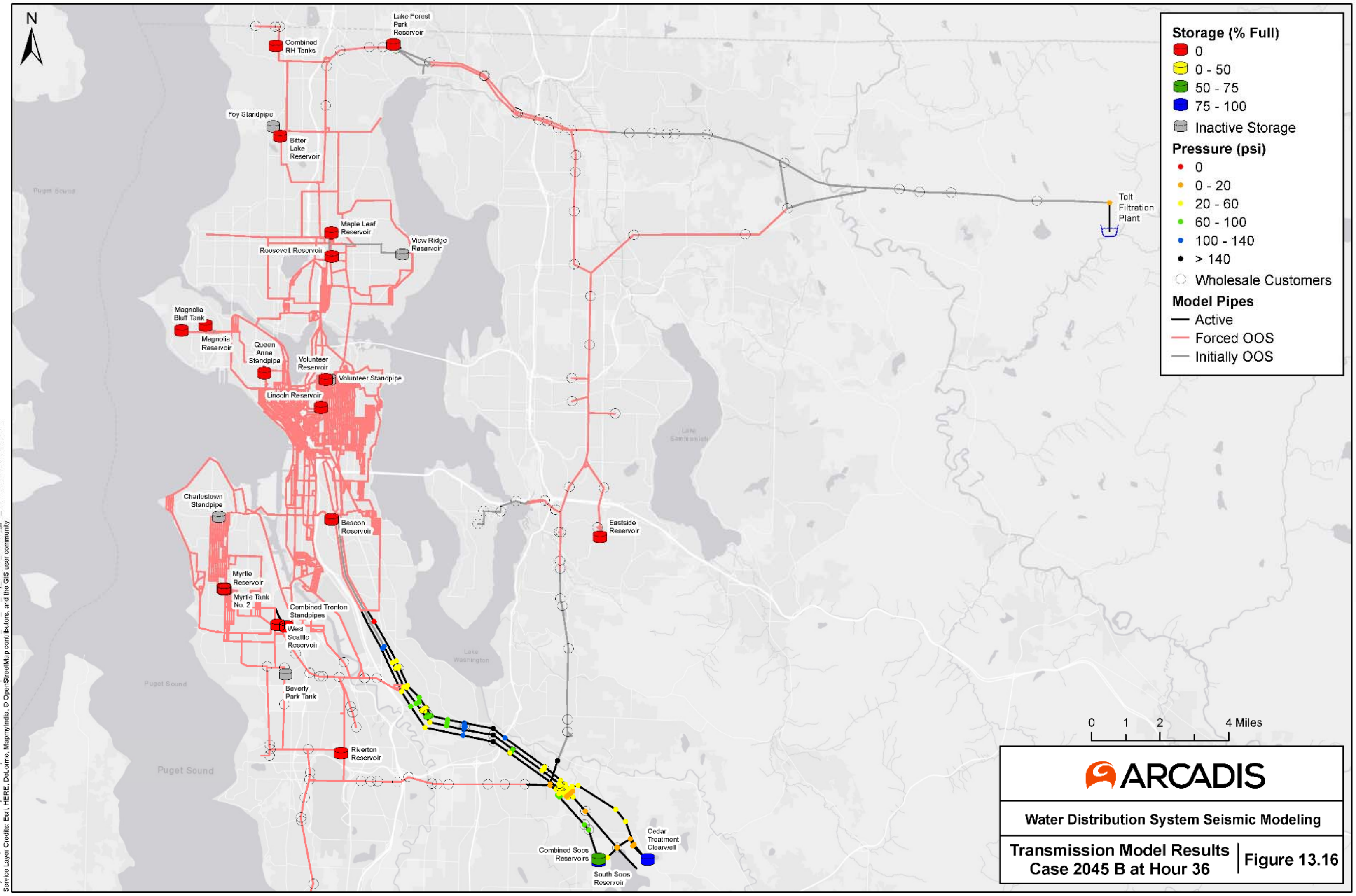


Water Distribution System Seismic Modeling

Transmission Model Results Case 2045 B at Hour 32 | **Figure 13.15**



ARCADIS

Water Distribution System Seismic Modeling

Transmission Model Results Case 2045 B at Hour 36 | **Figure 13.16**

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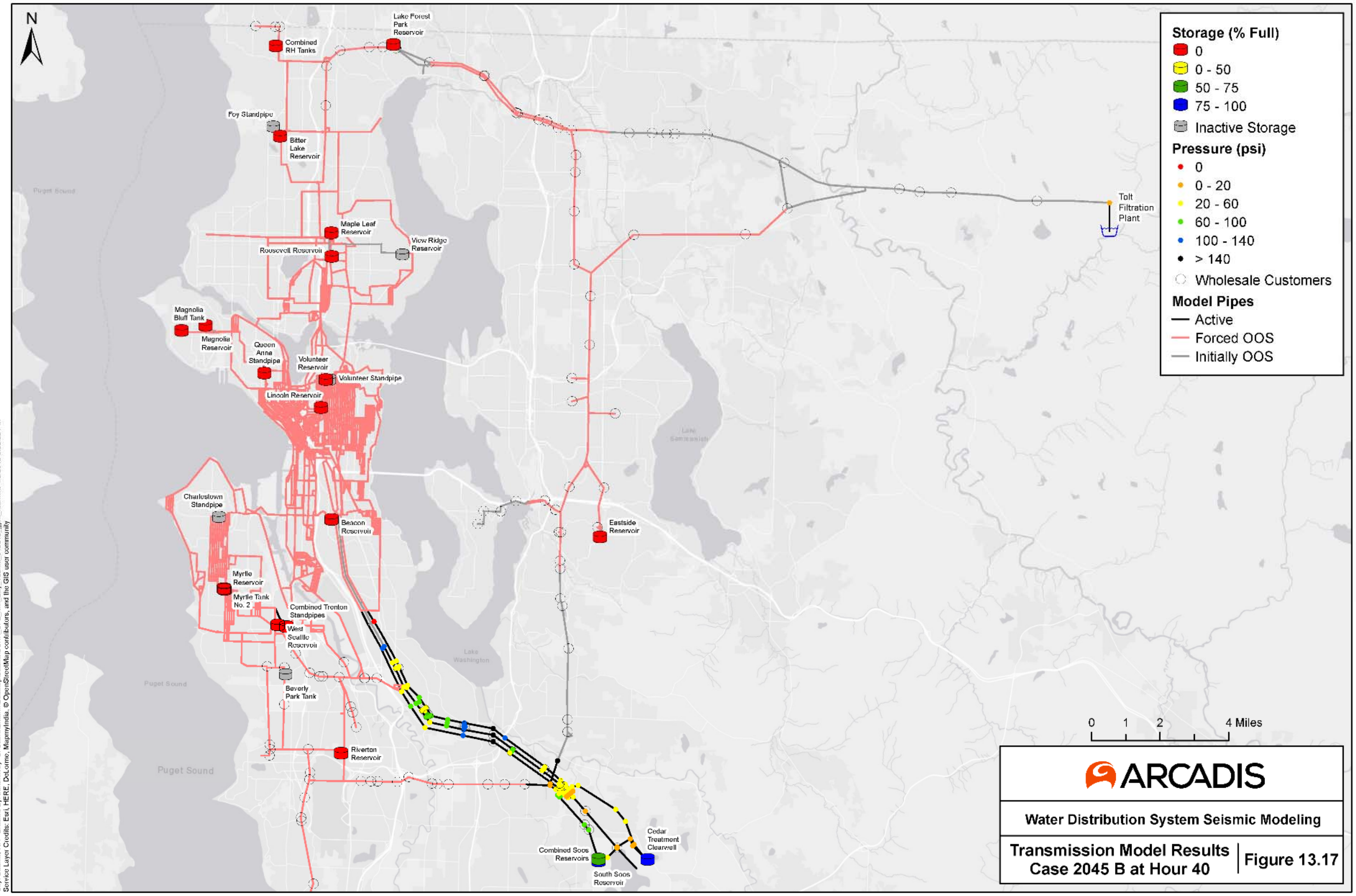

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
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Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
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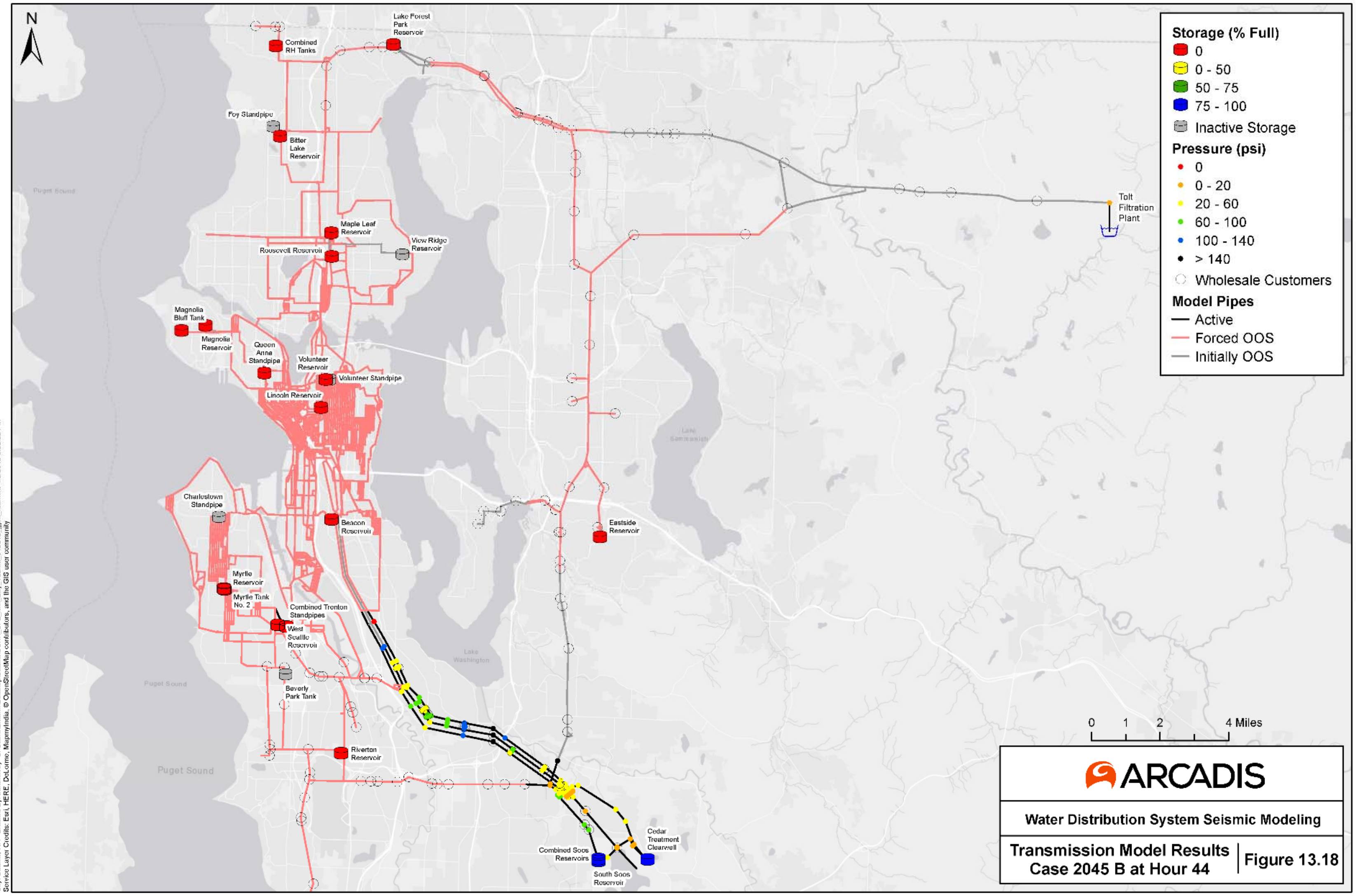
Riverton Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Tolt Filtration Plant
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Case 2045 B at Hour 40
Figure 13.17



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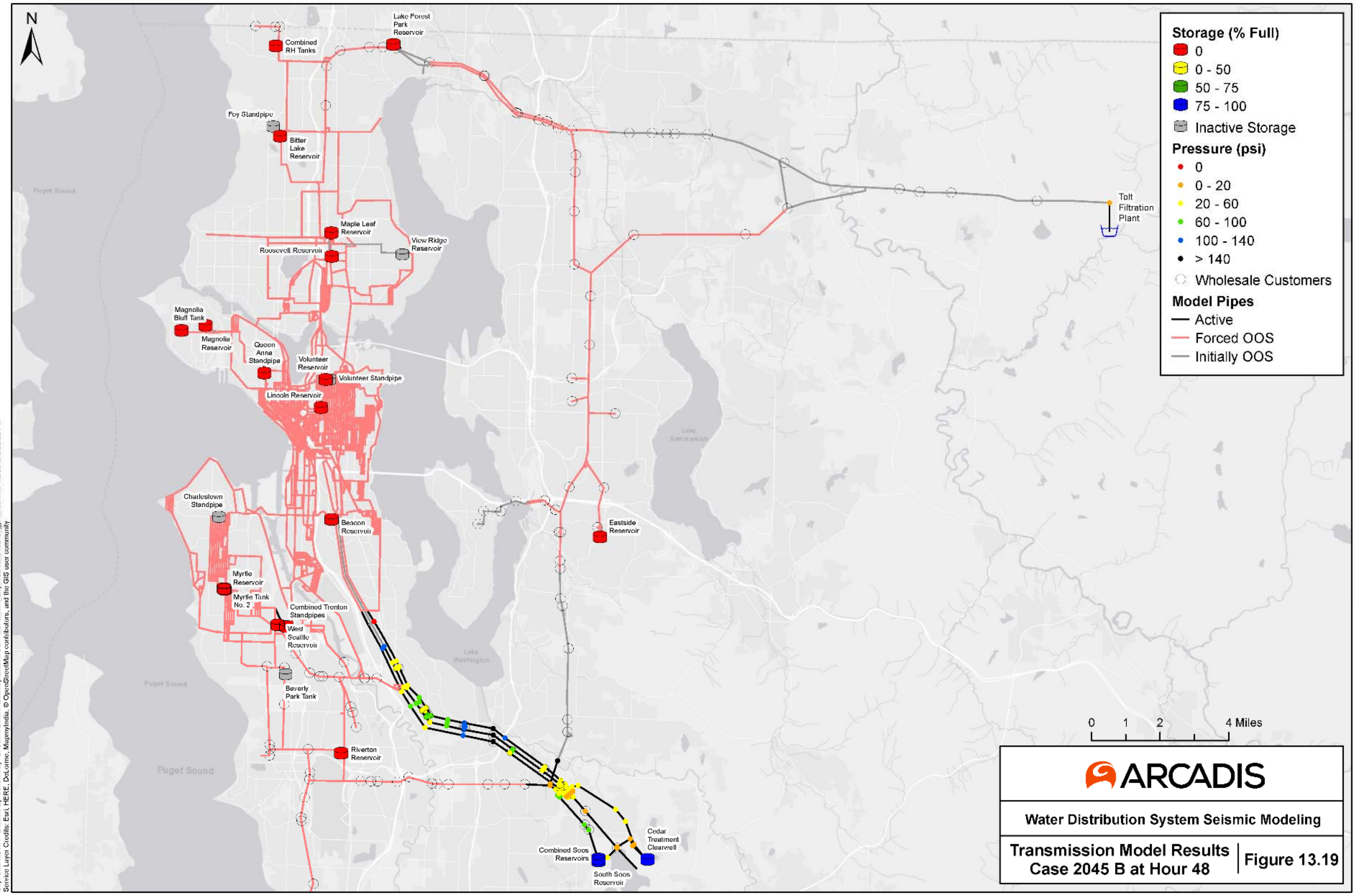

Water Distribution System Seismic Modeling

Transmission Model Results
Case 2045 B at Hour 48

Figure 13.19

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M7.0 Seattle Fault Zone Transmission Pipeline Year 2075 Improvement Case Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling
4/4/2018

Seattle Fault Seismic Event
Transmission Pipeline Simulations

Case 2075 A Tolt Filtration Plant supplies west up to Pipe 7031, not connected to the rest of the system;
From the Control Works (Cedar System), there is only a single 60-inch diameter pipeline that serves Seattle;
Eastside Supply Line, West Seattle Pipeline and Cedar River Pipeline #4 are online;
Facility upgrades are the same as the distribution system Case 2.

Model Results

Time (hrs)	Total System Demand (gpm)	Emitter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	395,094	307,309	87,785	85%	306.6
3	377,182	289,801	87,381	84%	254.2
12	333,482	249,800	83,682	73%	130.5
22	228,458	170,381	58,077	52%	63.5
32	204,855	146,999	57,856	52%	48.9
48	179,129	121,919	57,210	49%	33.2

Model Regions Forced Out of Service During Simulation

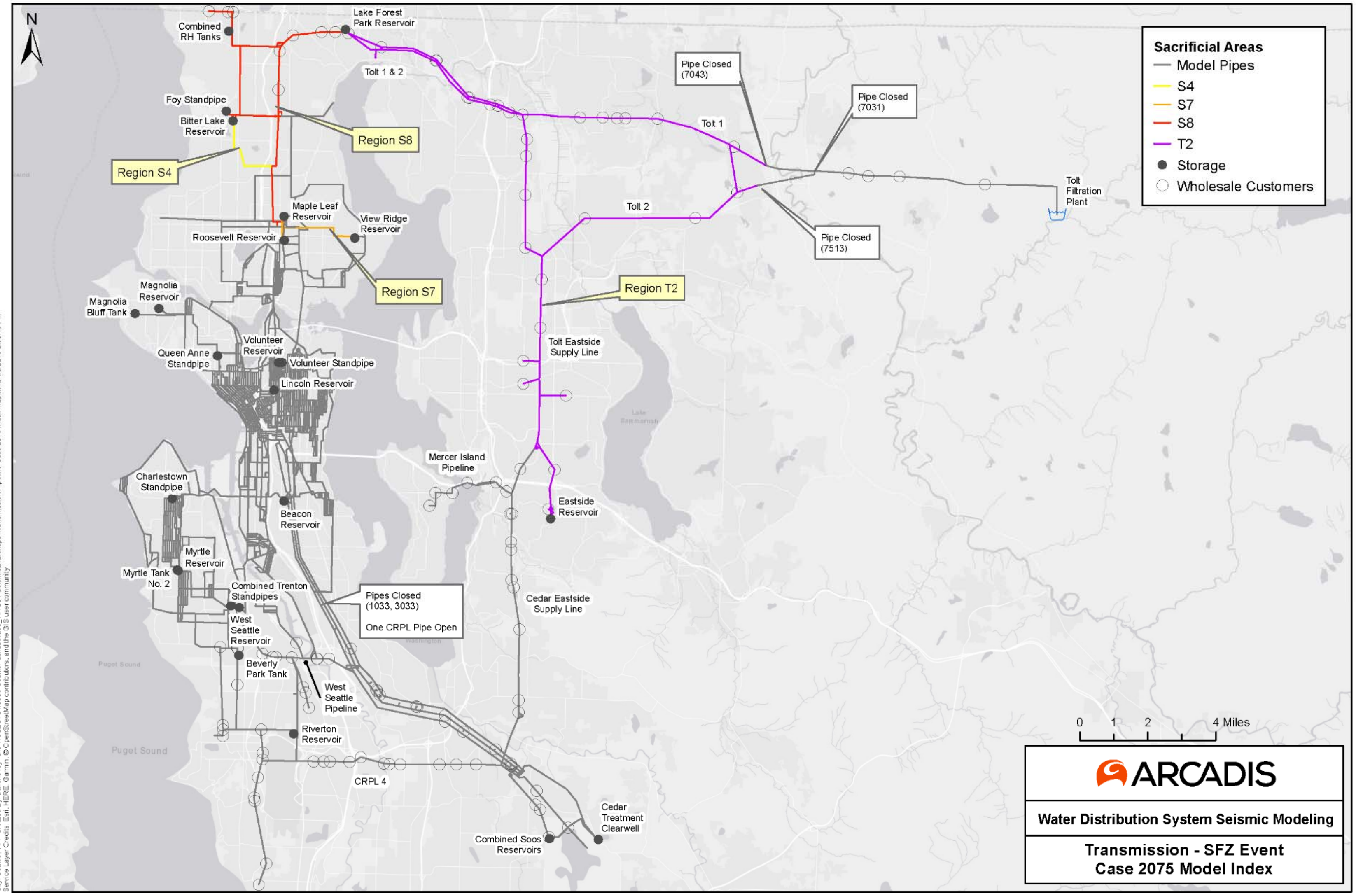
Time	Region
12	S7
21	S4
21	S8

Model Simulation Notes

1. *All wholesale customers assumed to start with 1.8 multiplier (max day demands)*
2. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
3. *Total Model Demands with elevated wholesale customers is 91,957 gpm*
4. *Satisfied Demands assume junction pressure greater than 0 psi*
5. *System Positive Pressure based on number of junctions above 0 psi out of the entire model*

Model Results Figure Index

Fig. 14.1	Hr 0	Fig. 14.5	Hr 8	Fig. 14.9	Hr 16	Fig. 14.13	Hr 24	Fig. 14.17	Hr 40
Fig. 14.2	Hr 2	Fig. 14.6	Hr 10	Fig. 14.10	Hr 18	Fig. 14.14	Hr 28	Fig. 14.18	Hr 44
Fig. 14.3	Hr 4	Fig. 14.7	Hr 12	Fig. 14.11	Hr 20	Fig. 14.15	Hr 32	Fig. 14.19	Hr 48
Fig. 14.4	Hr 6	Fig. 14.8	Hr 14	Fig. 14.12	Hr 22	Fig. 14.16	Hr 36		



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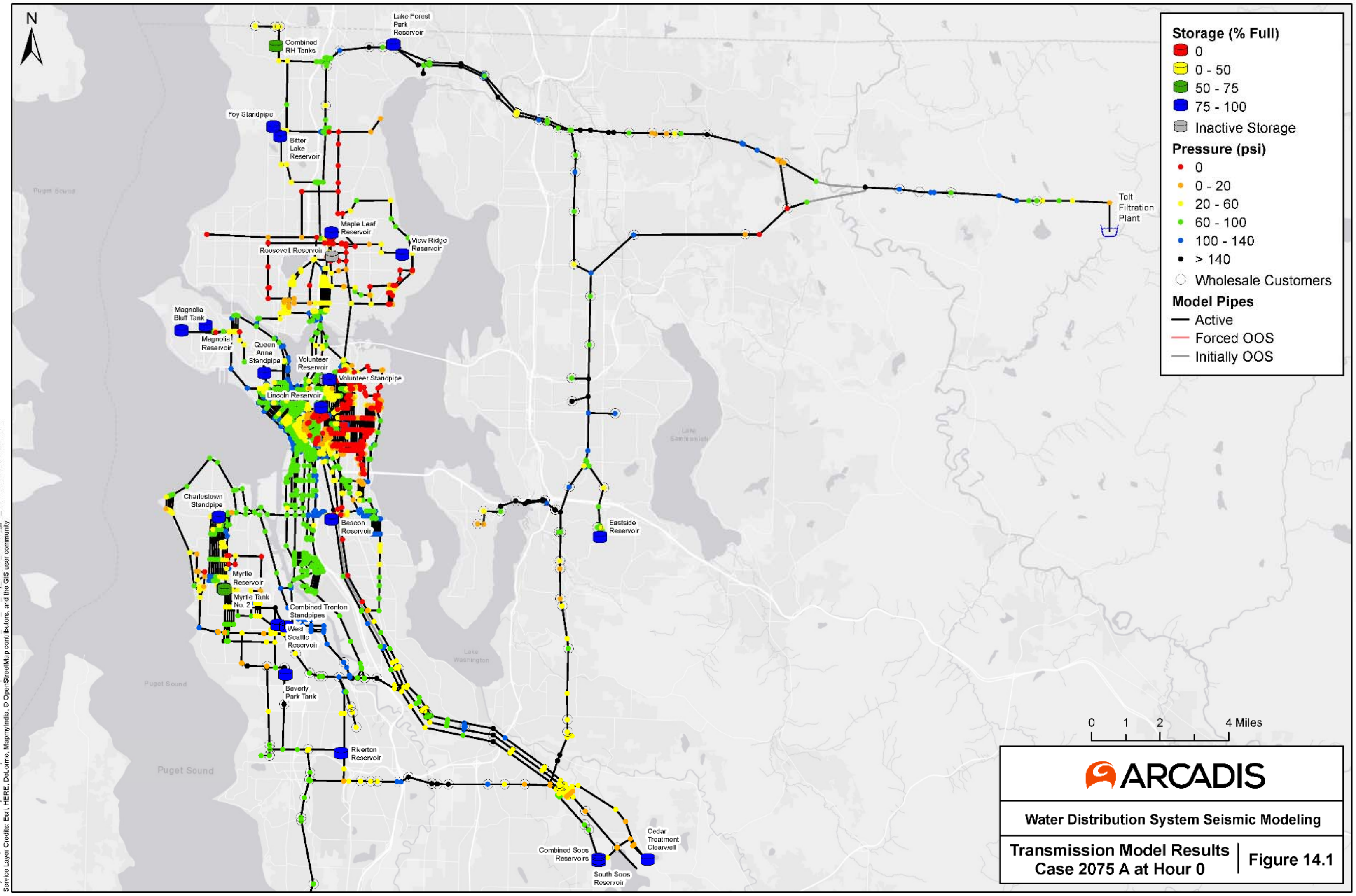
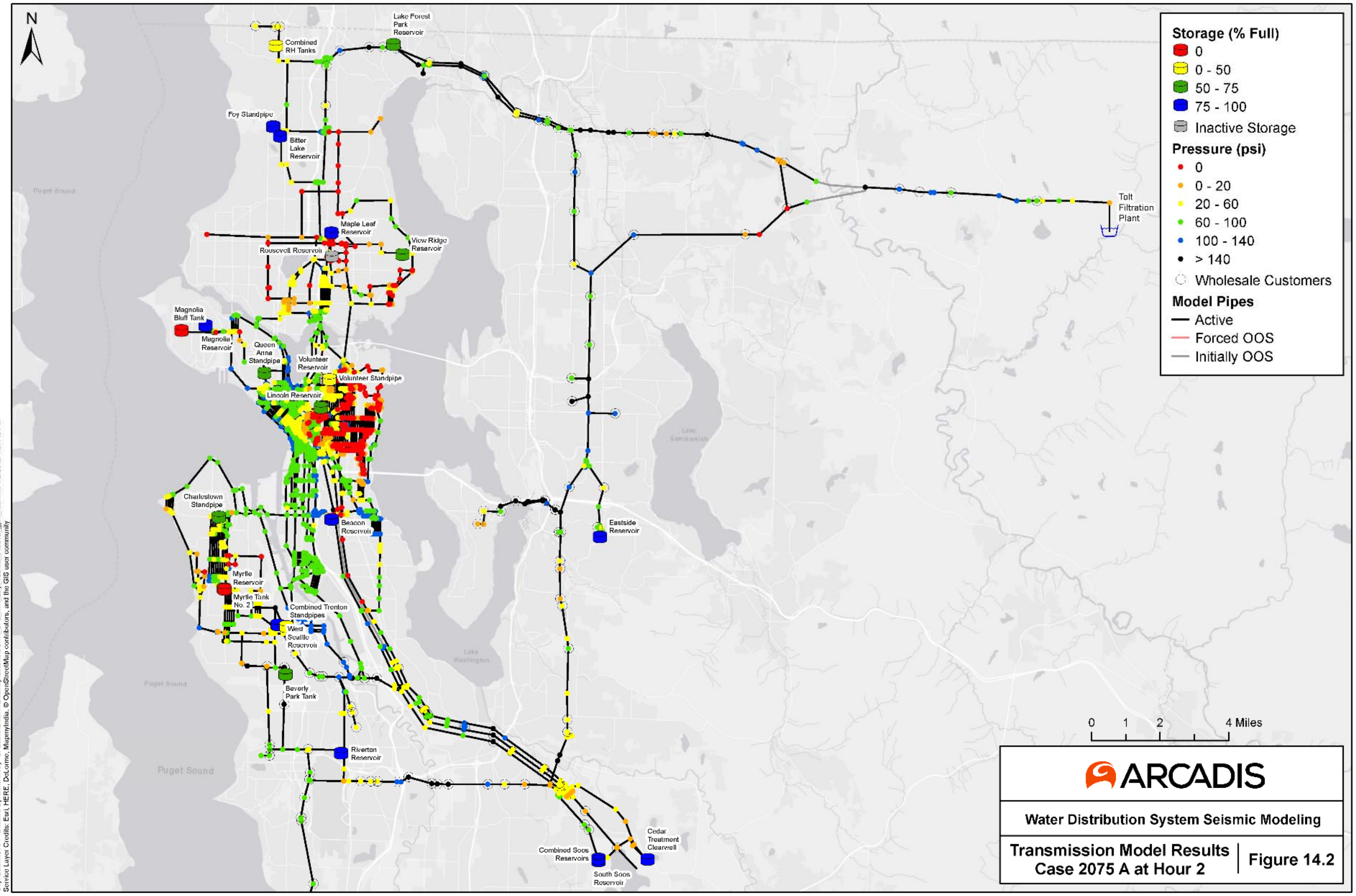


Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 0
Figure 14.1
N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish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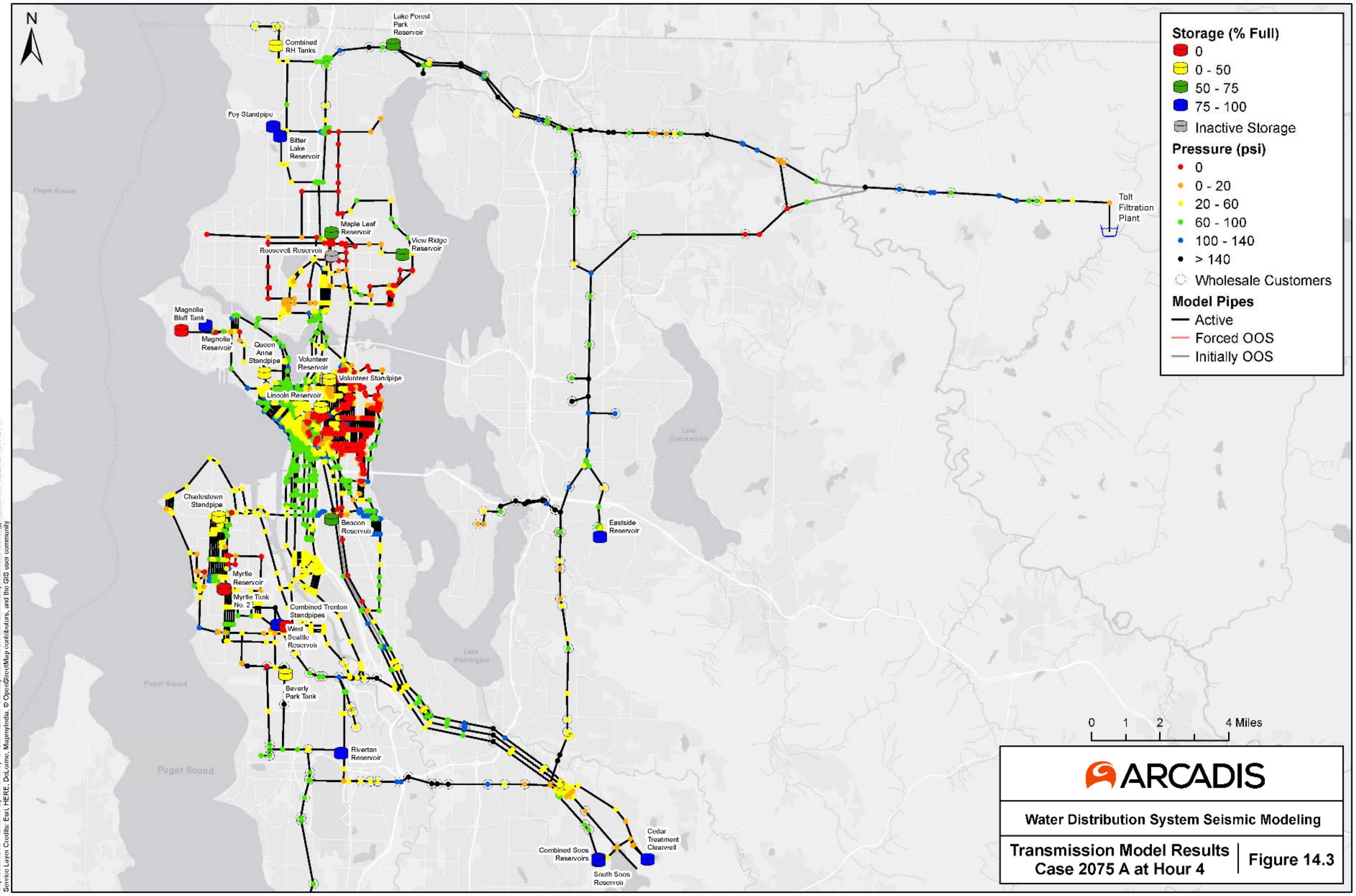
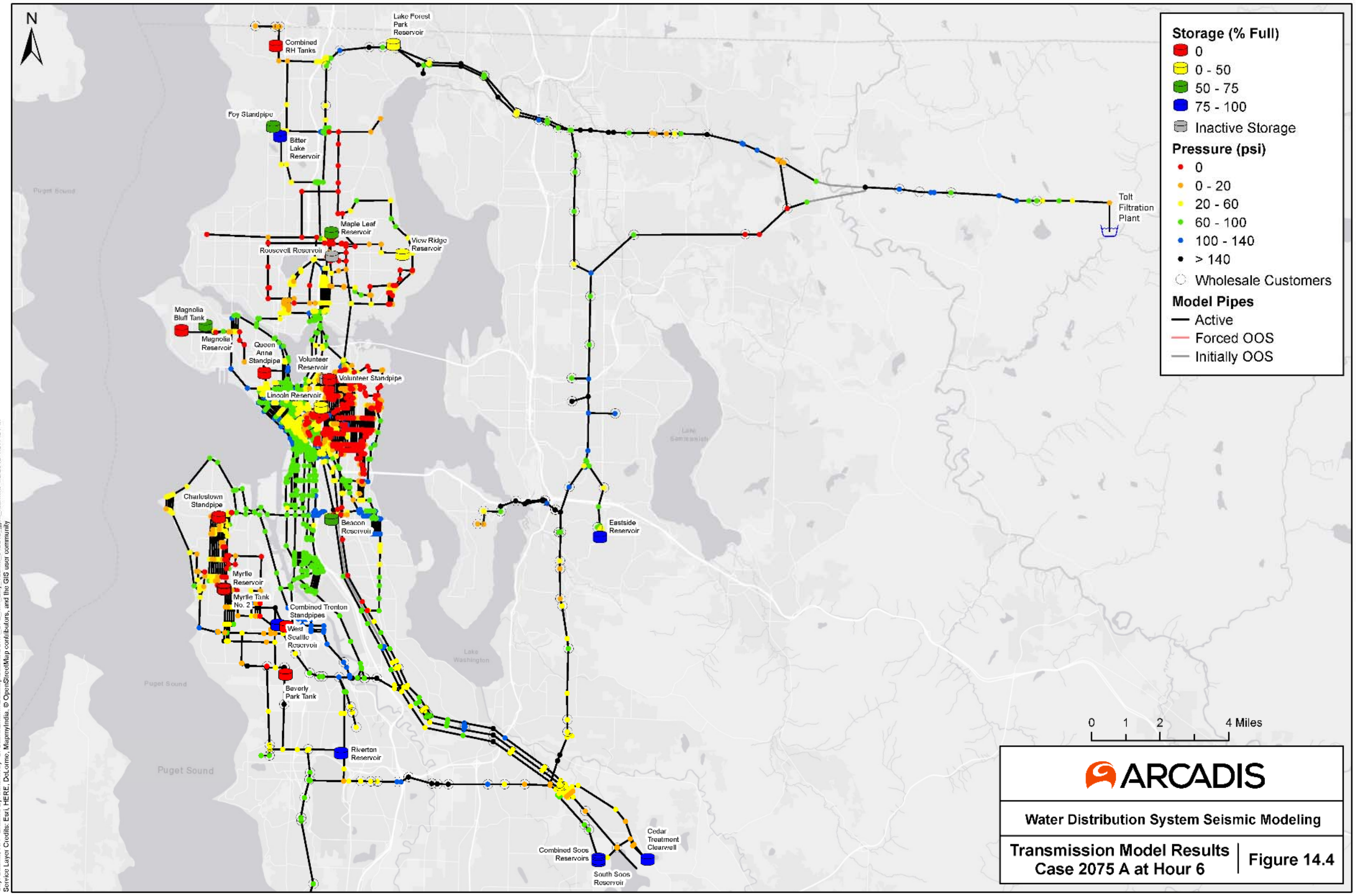
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Tolt Filtration Plant
Puget Sound
Lake Washington
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 2
Figure 14.2



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0
1
2
4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 4
Figure 14.3
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish



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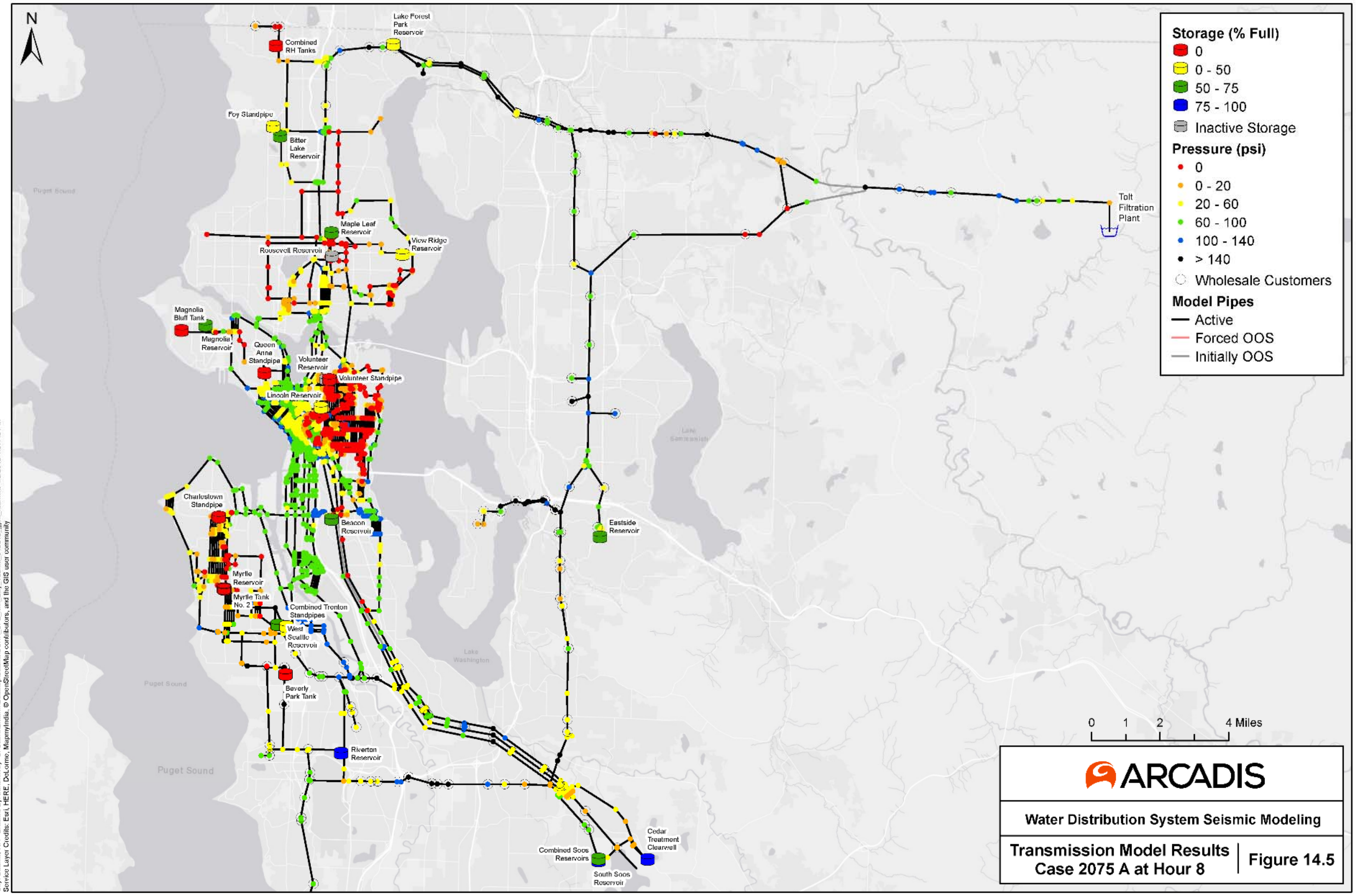

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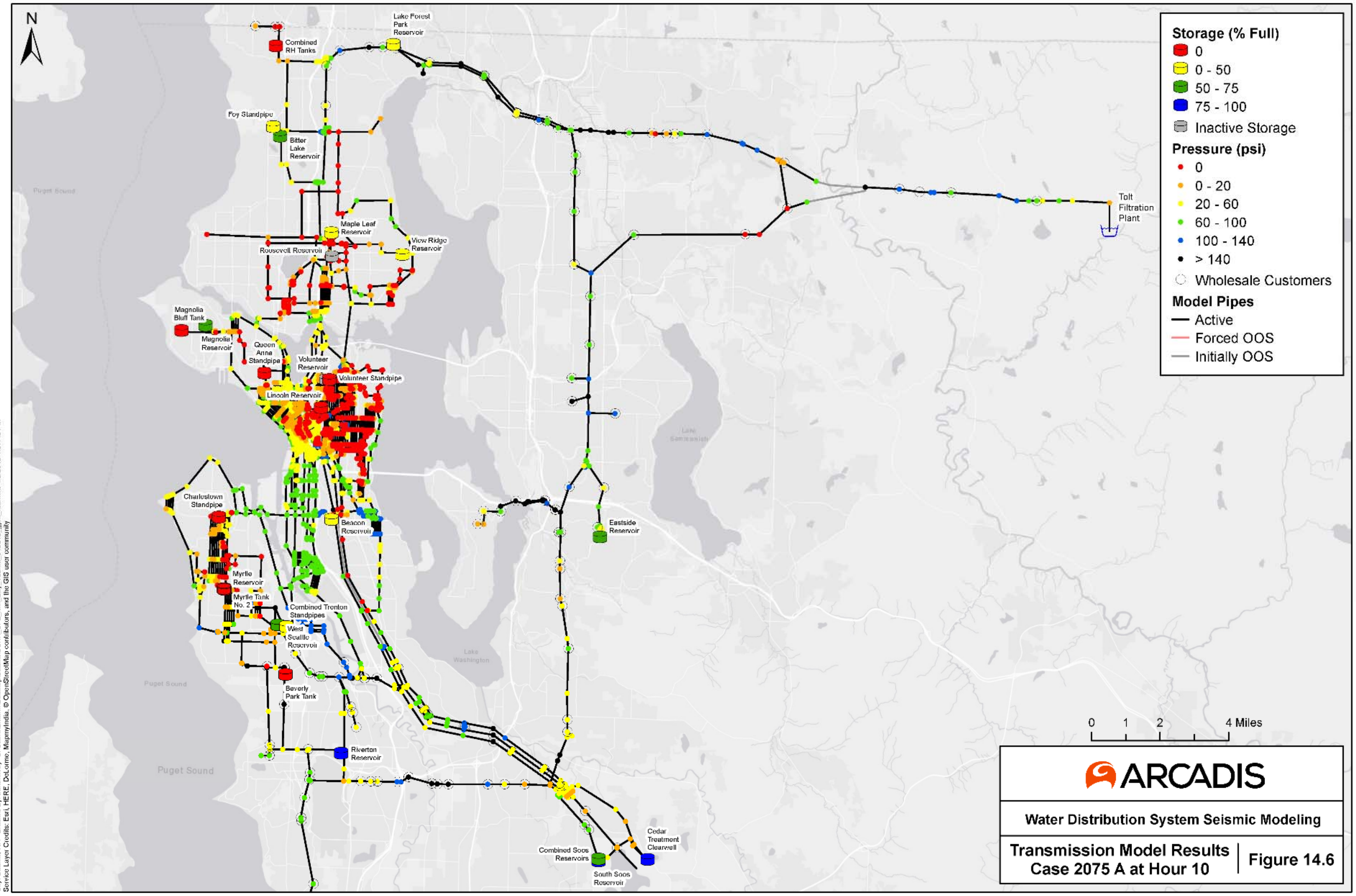
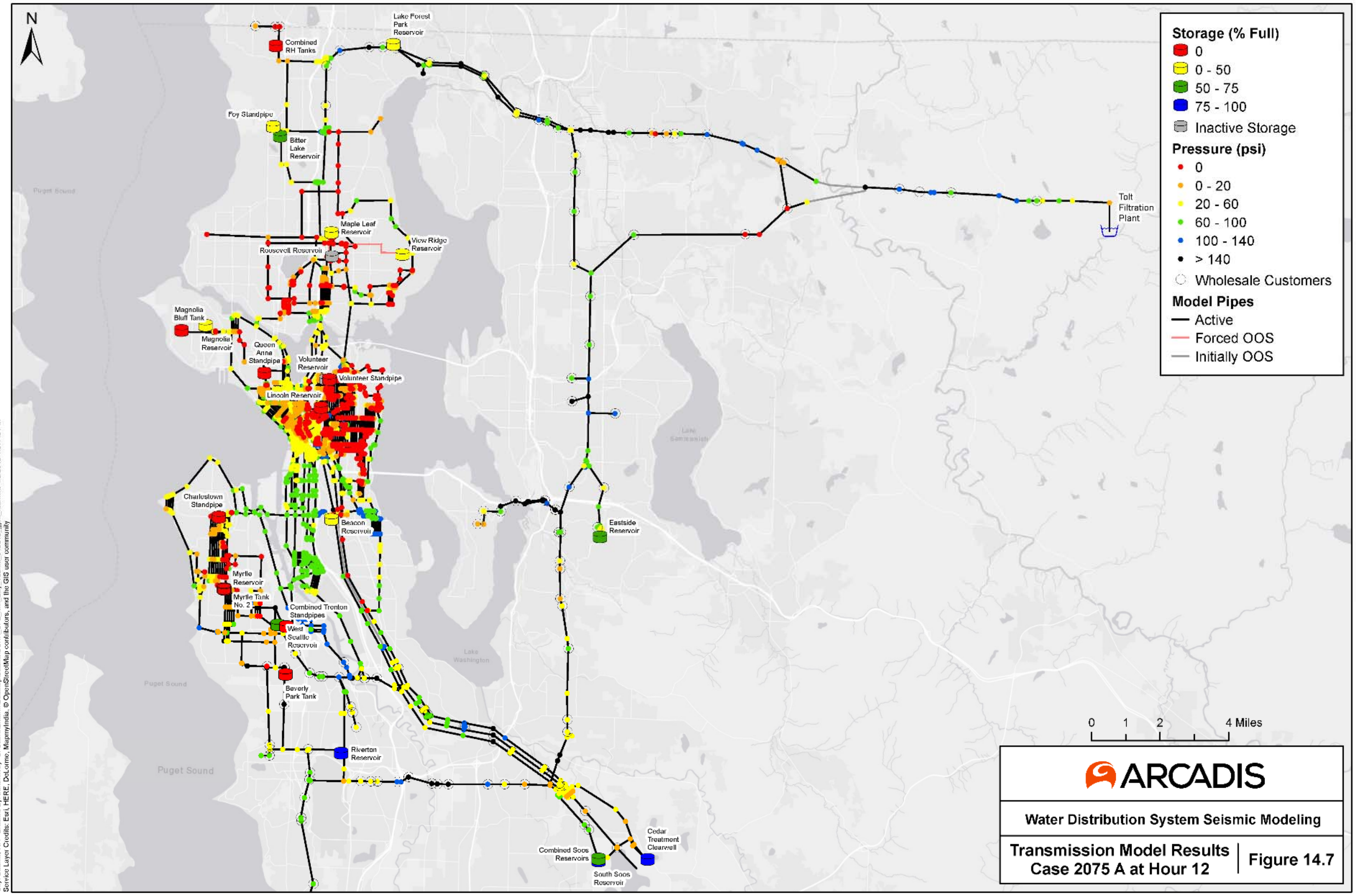
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



Water Distribution System Seismic Modeling

Transmission Model Results Case 2075 A at Hour 10

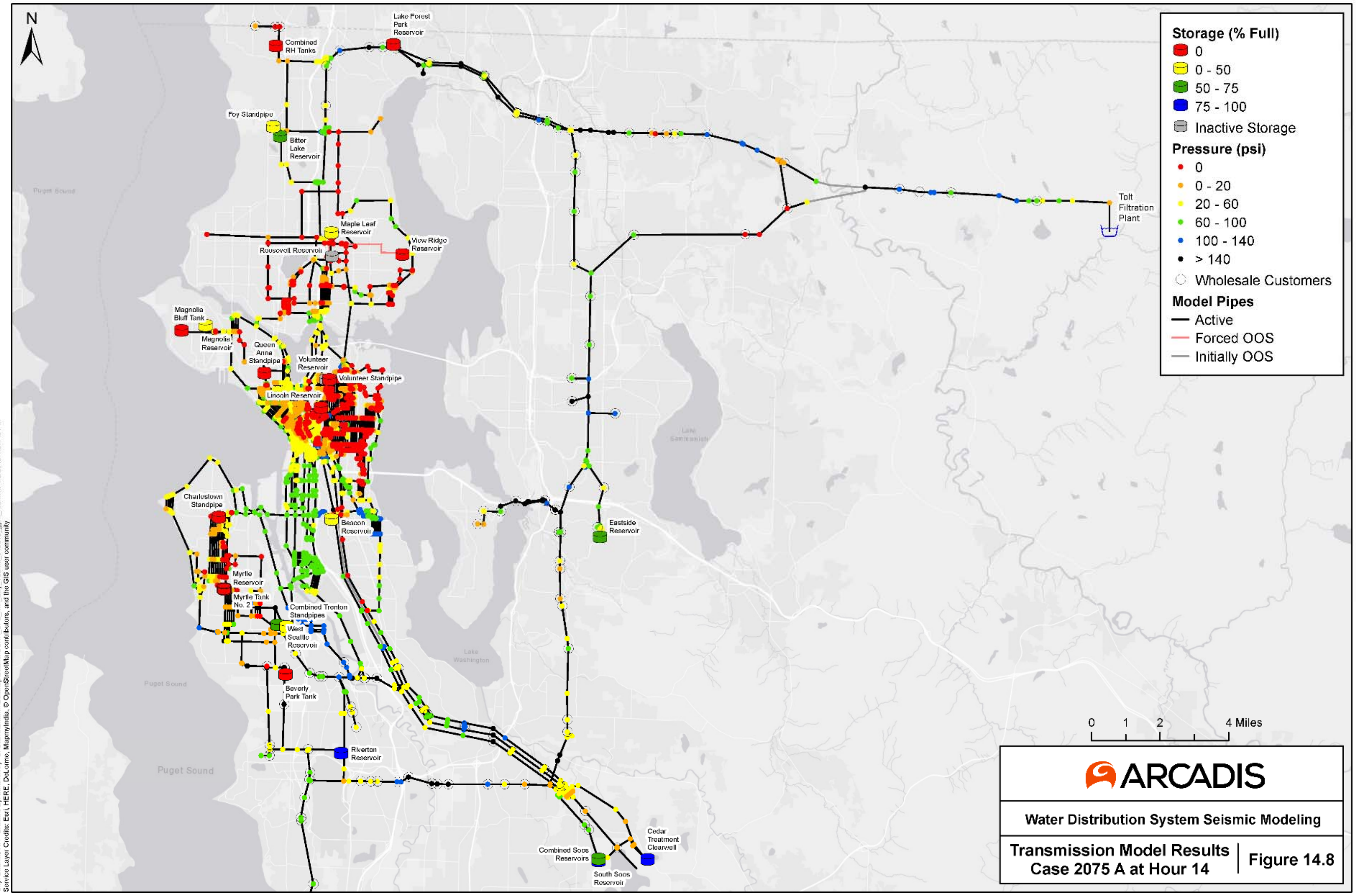
Figure 14.6



ARCADIS

Water Distribution System Seismic Modeling

Transmission Model Results Case 2075 A at Hour 12 | **Figure 14.7**



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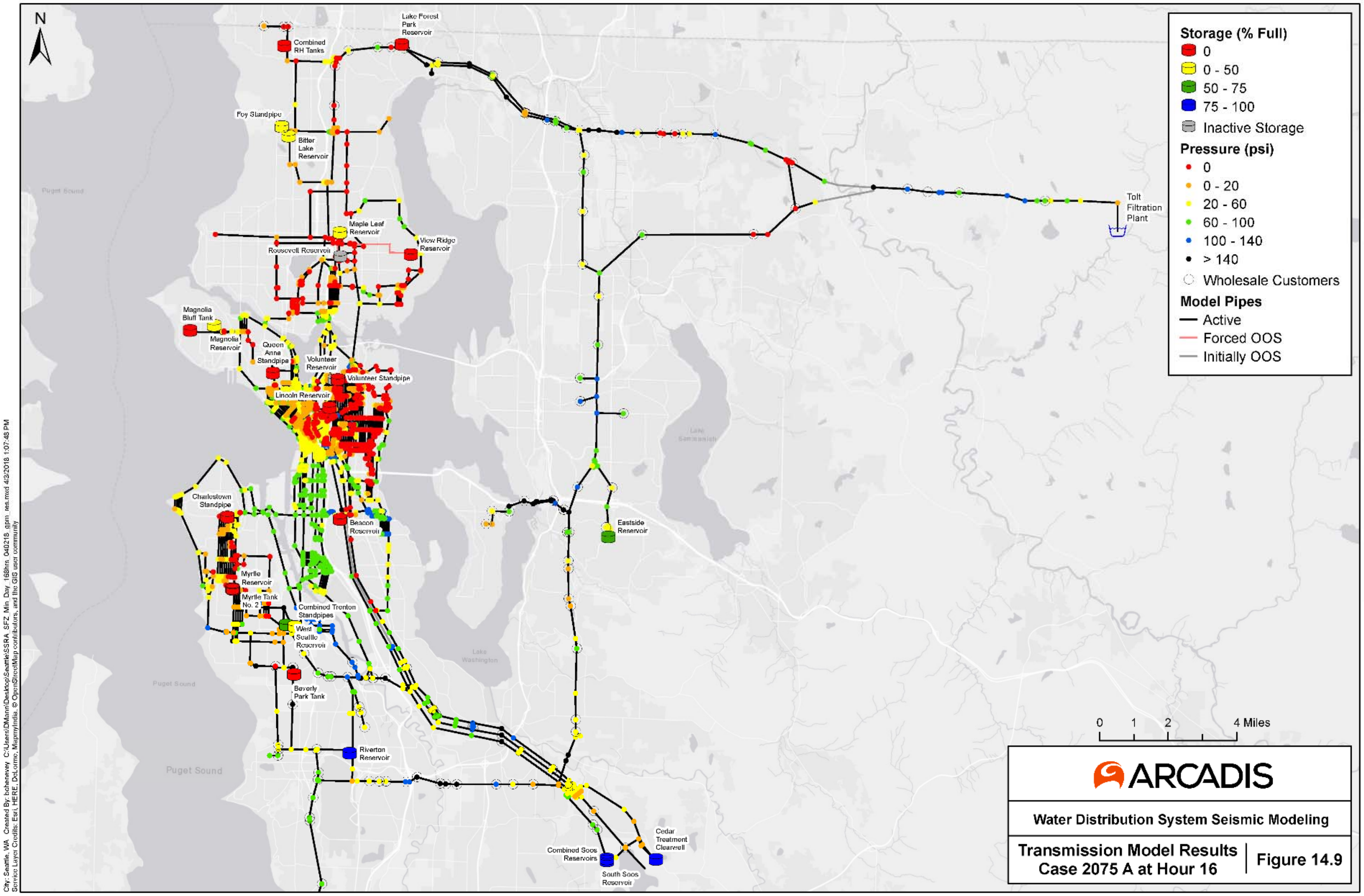

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Lake Forest Park Reservoir
Combined RH Tanks
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View Ridge Reservoir
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City: Seattle, WA Created By: bchenevey C:\Users\DMann\Desktop\Seattle\SSRA_SFZ_Min_Day_168hrs_040218_gpm_res.mxd 4/3/2018 1:07:48 PM
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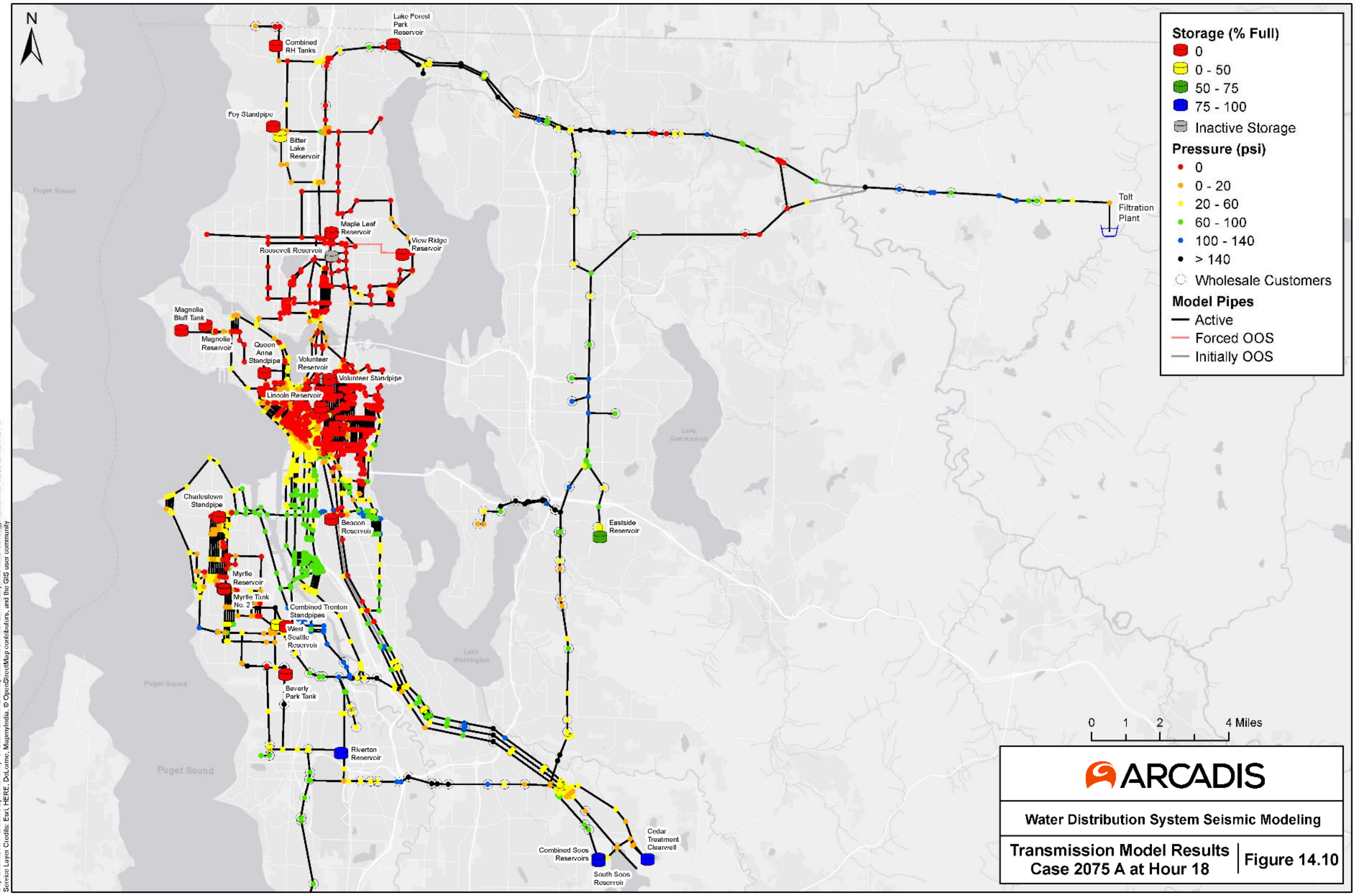
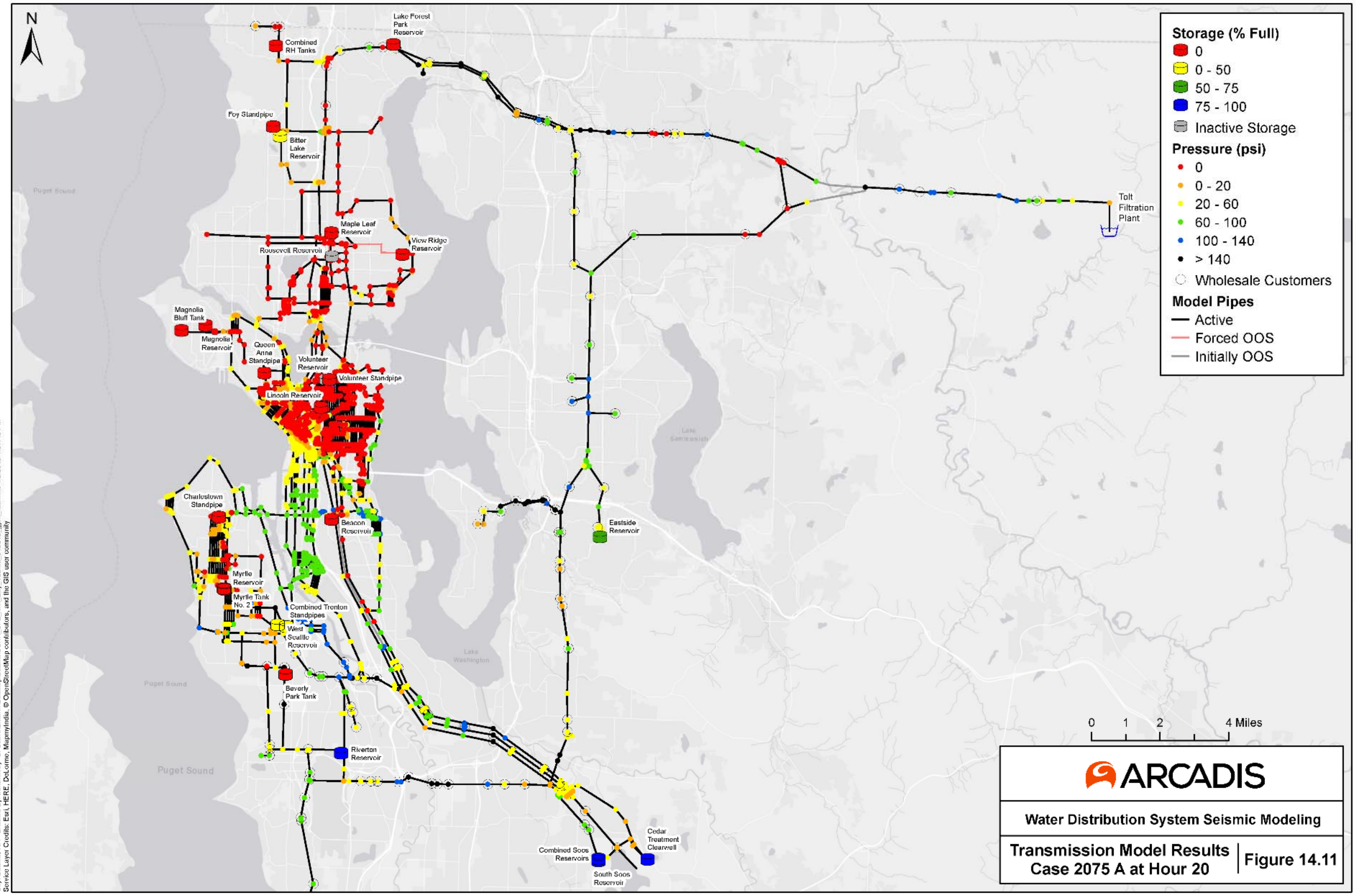
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 16
Figure 14.9



ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results Case 2075 A at Hour 18
Figure 14.10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0 - 50
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Inactive Storage
Pressure (psi)
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60 - 100
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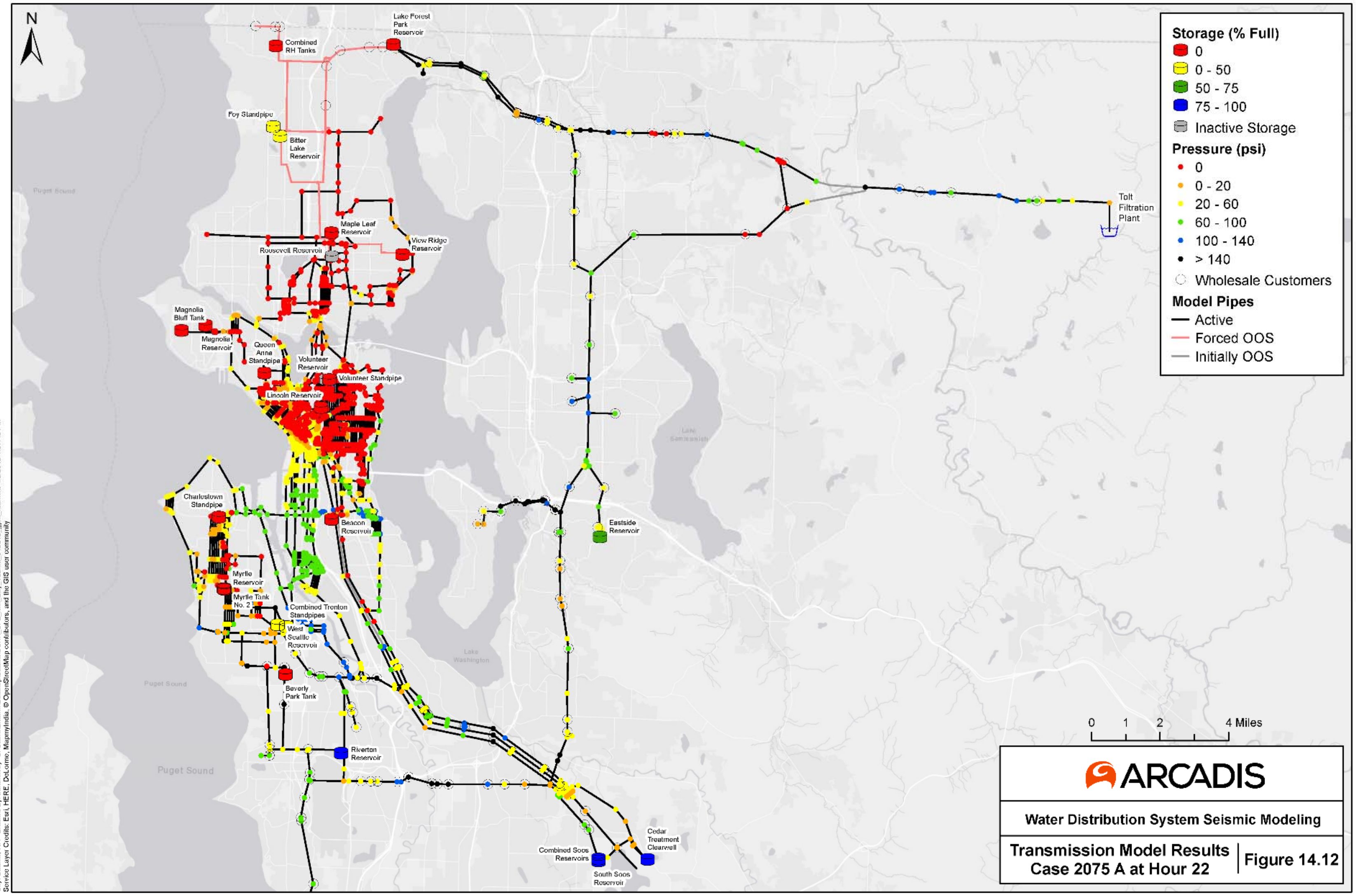
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 20
Figure 14.11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0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 22
Figure 14.12
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
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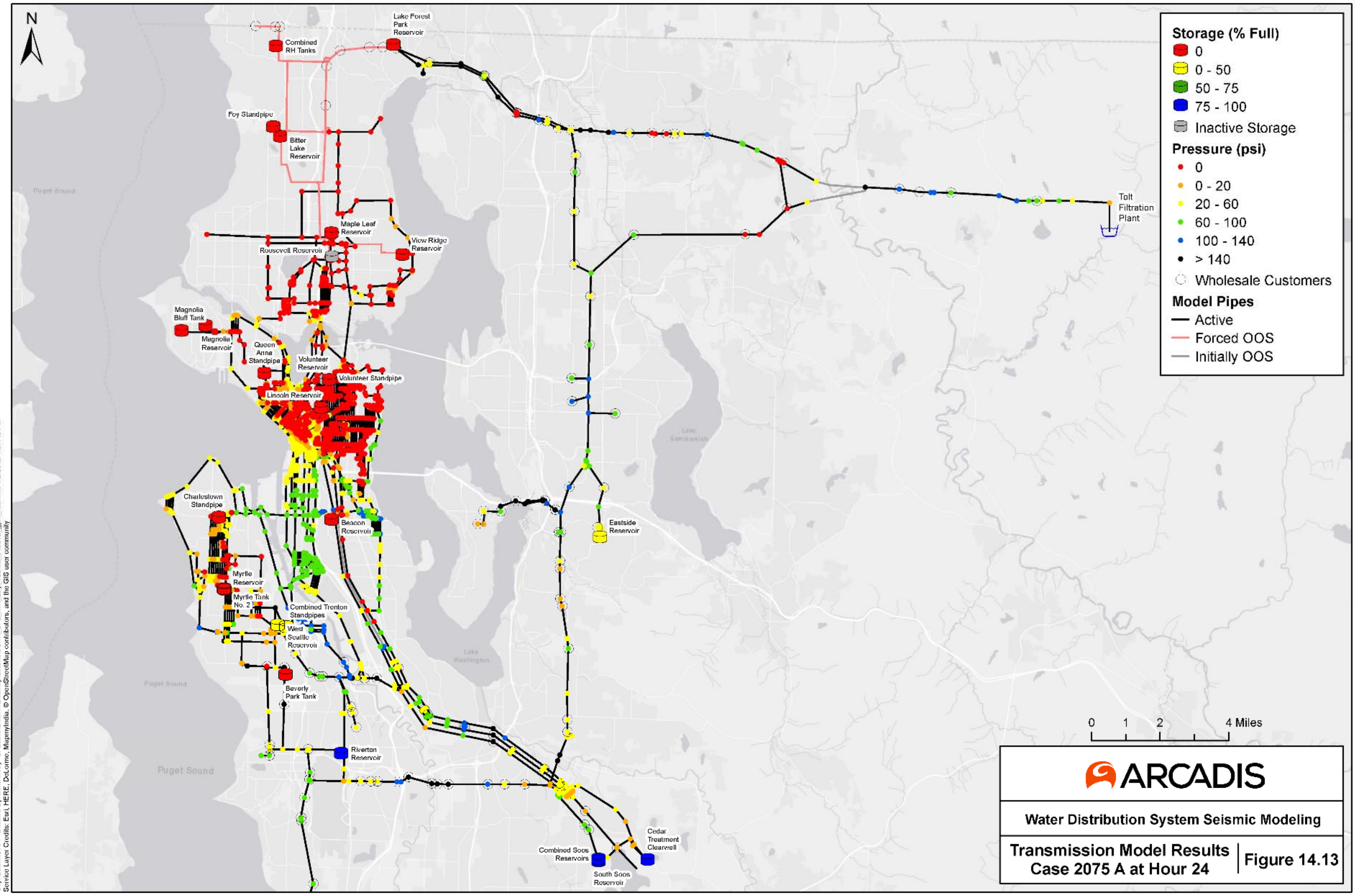
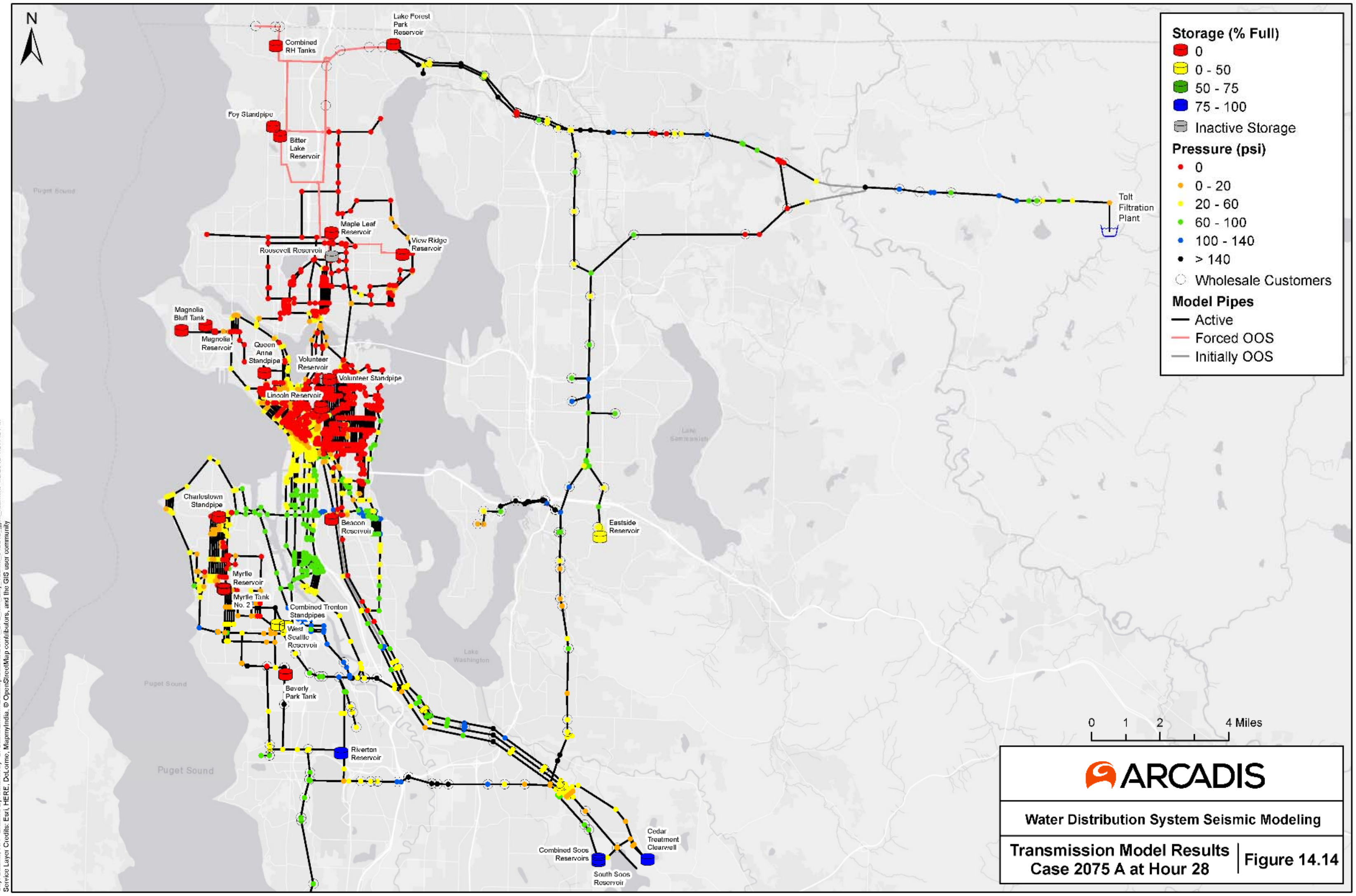

N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Cedar Treatment Clearwell
Combined Soos Reservoirs
South Soos Reservoir
Puget Sound
Puget Sound
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 24
Figure 14.13



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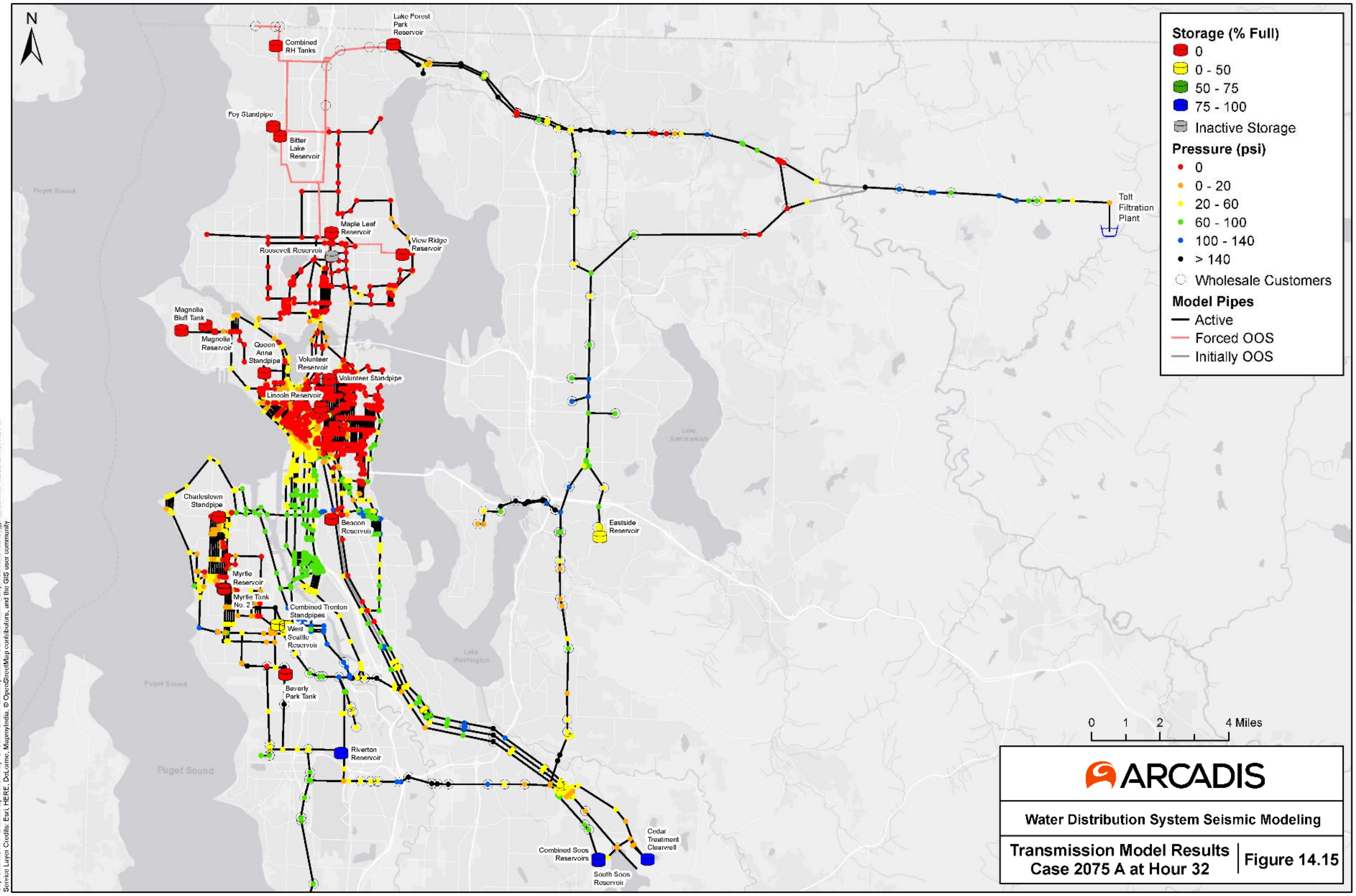

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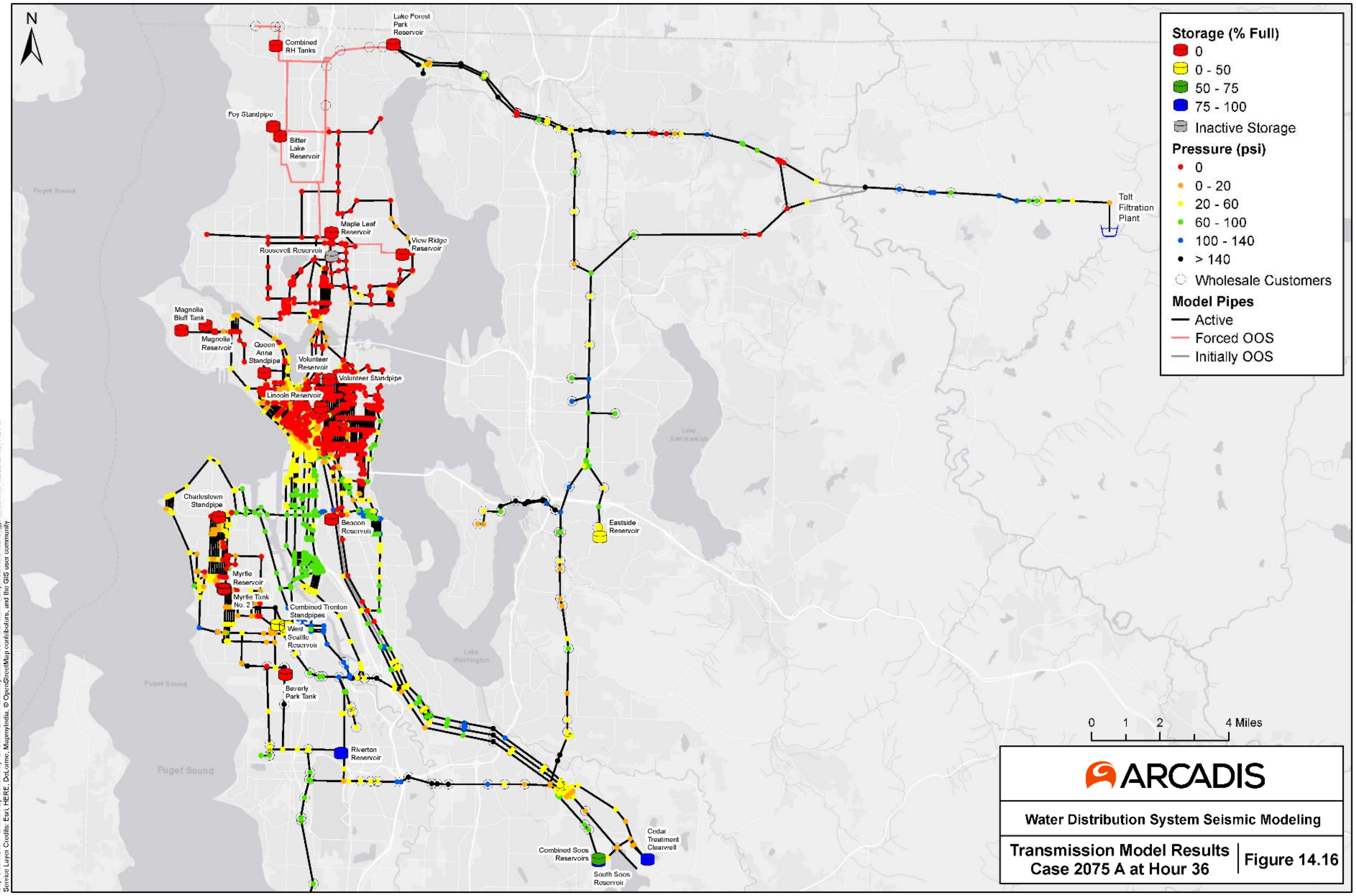
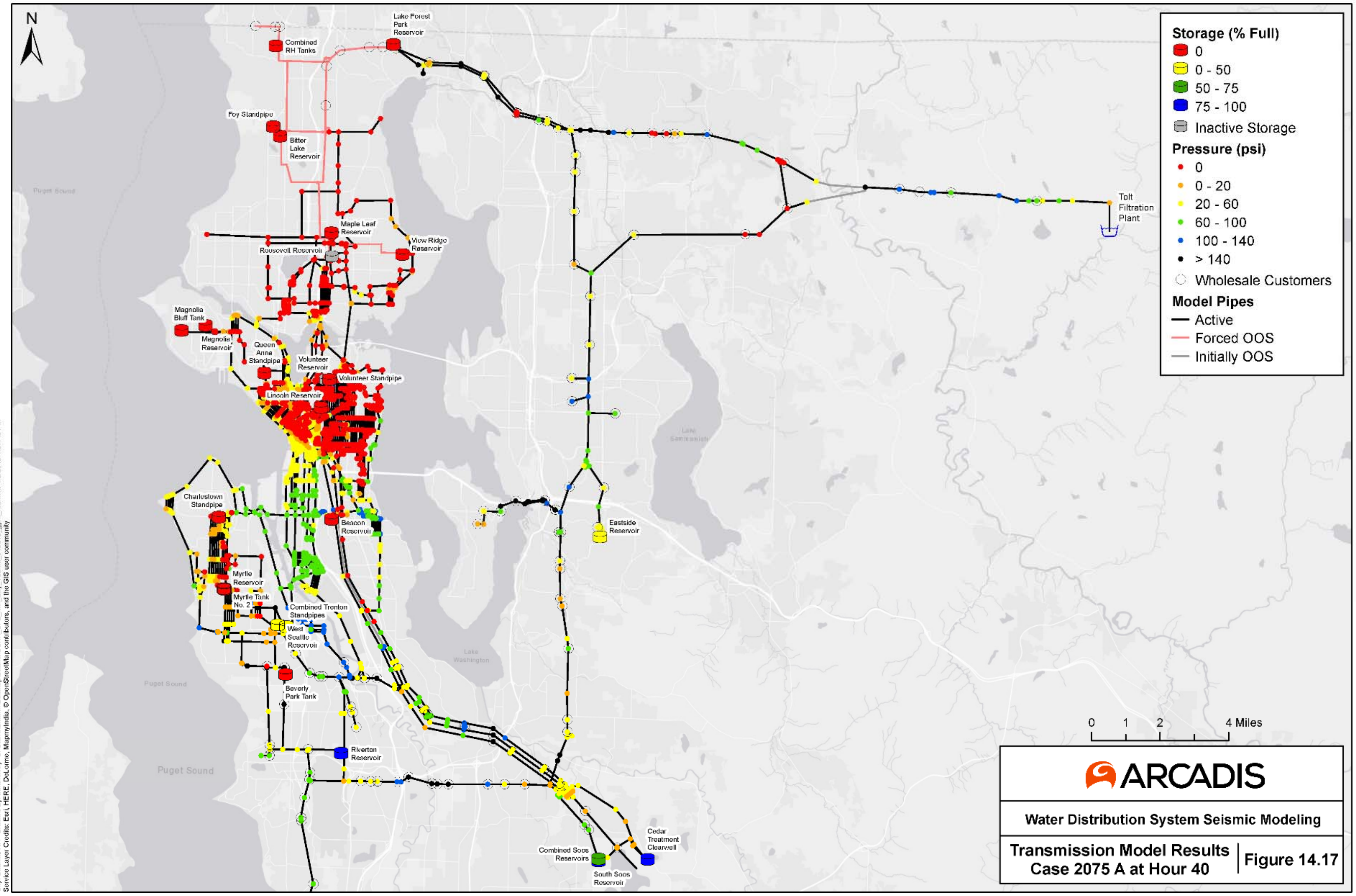
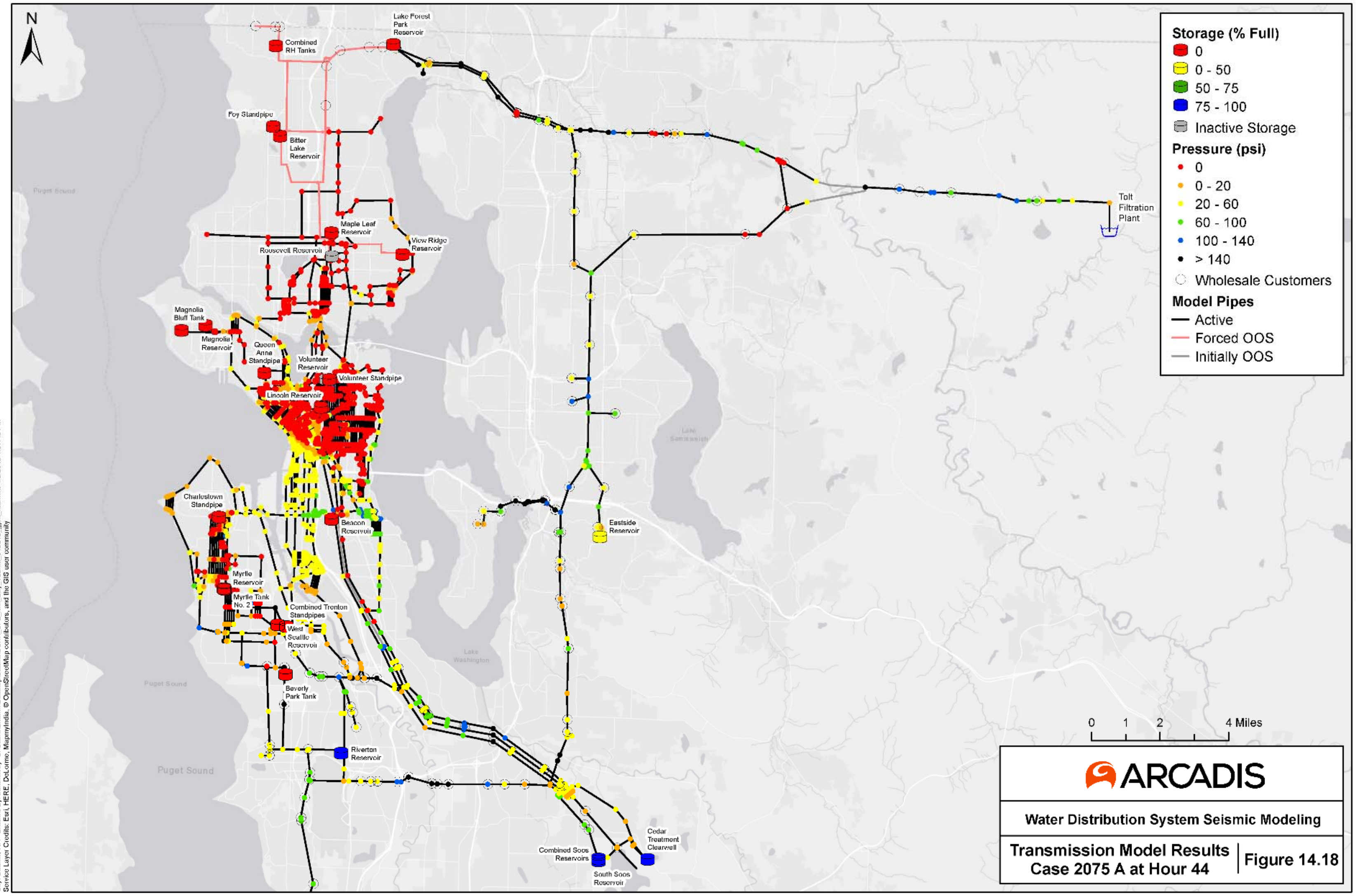
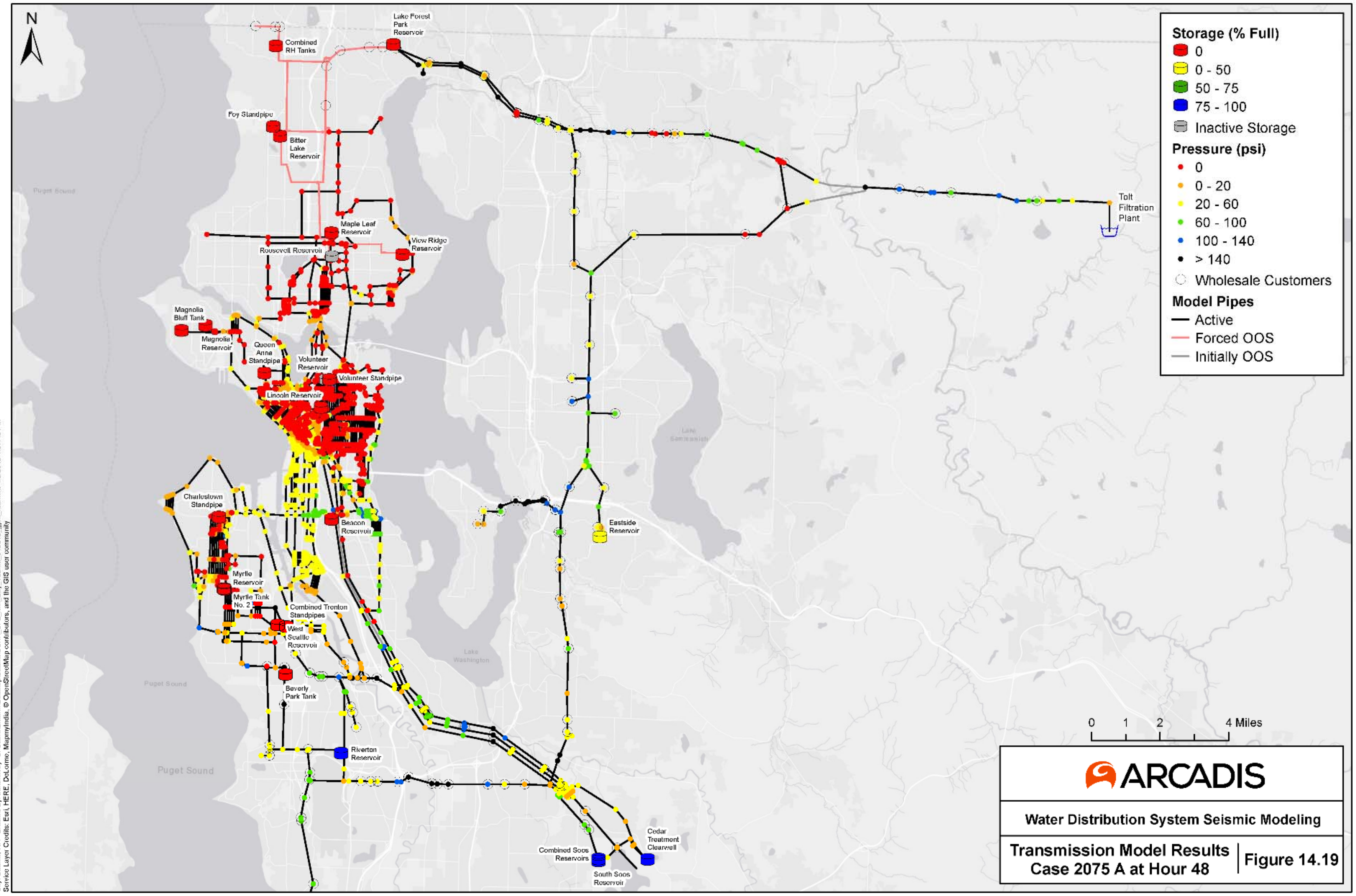

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 36
Figure 14.16



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 40
Figure 14.17



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Tolt Filtration Plant
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 A at Hour 44
Figure 14.18



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M7.0 Seattle Fault Zone Transmission Pipeline Year 2075 Improvement Case with Roosevelt and Volunteer Reservoirs Online Hydraulic Modeling Results

ARCADIS Design & Consultancy for natural and built assets

Water Distribution System Seismic Modeling

4/4/2018

Seattle Fault Seismic Event
Transmission Pipeline Simulations

Case 2075 B

Tolt Filtration Plant supplies west up to Pipe 7031, not connected to the rest of the system;
From the Control Works (Cedar System), there is only a single 60-inch diameter pipeline that serves Seattle;
Eastside Supply Line, West Seattle Pipeline, and Cedar River Pipeline #4 are online;
Facility upgrades are the same as the distribution system Case 4 (Volunteer and Roosevelt Reservoirs are online).

Model Results

Time (hrs)	Total System Demand (gpm)	Emitter Flows (gpm)	Supplied Demands (gpm)	System Positive Pressure (%)	Available System Storage (MG)
0	410,689	321,276	89,413	92%	360.1
3	377,468	288,653	88,815	89%	304.8
12	341,173	256,650	84,523	76%	169.6
22	269,239	206,456	62,782	69%	81.1
32	222,613	161,982	60,632	62%	50.1
48	179,247	122,256	56,991	48%	33.3

Model Regions Forced Out of Service During Simulation

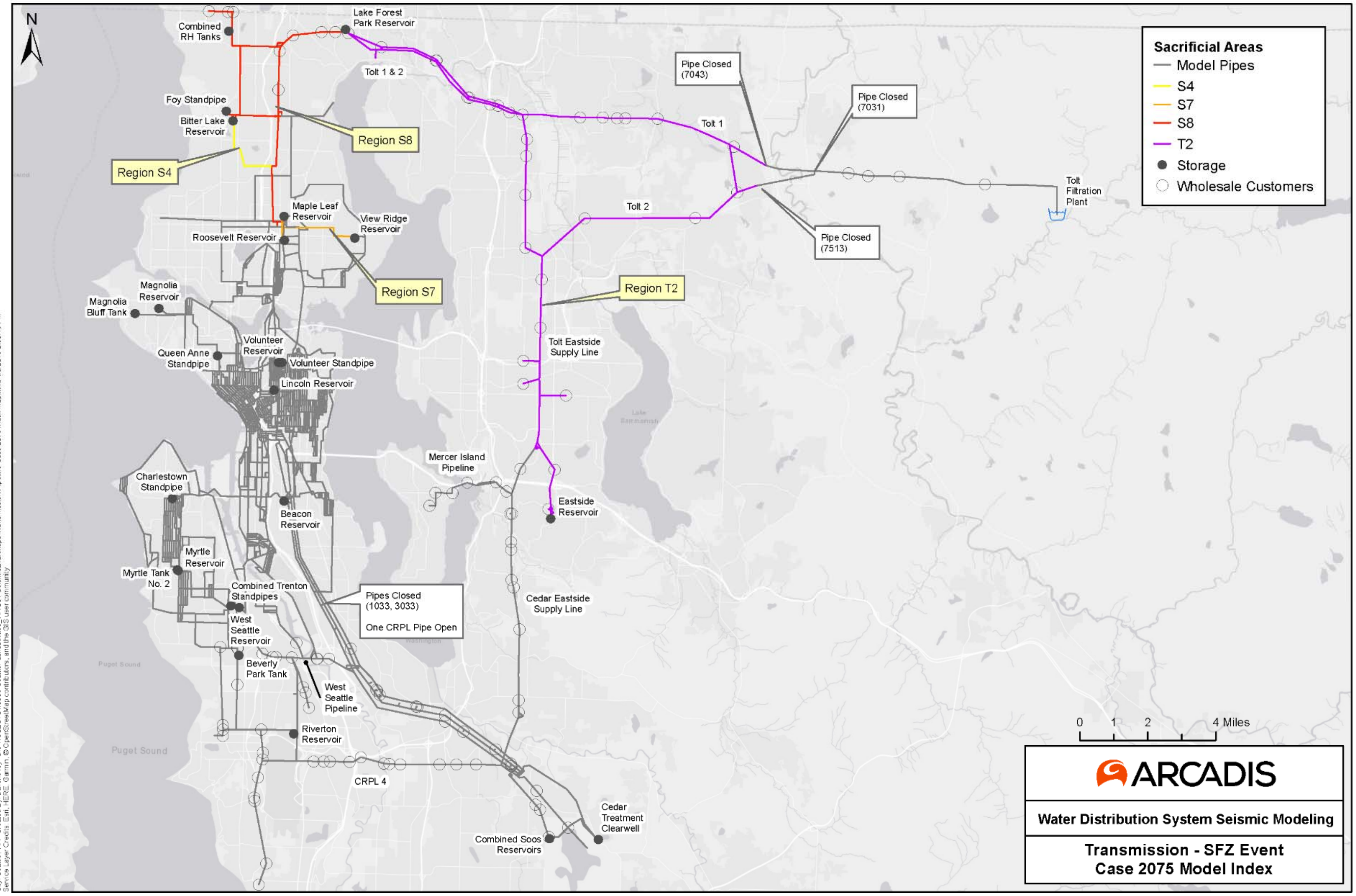
Time	Region
12	S7
21	S4
21	S8

Model Simulation Notes

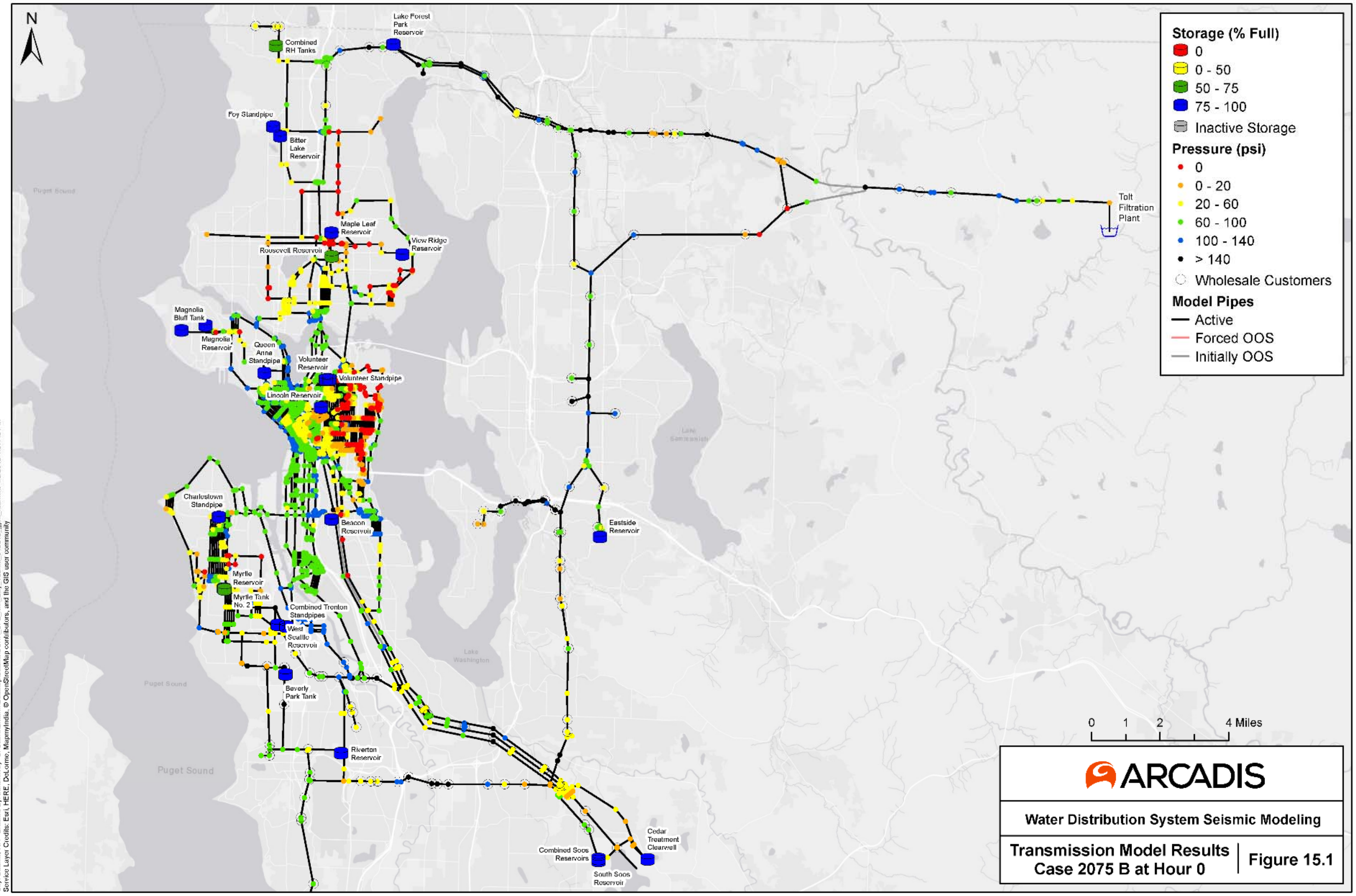
1. *All wholesale customers assumed to have max day demands with 1.8 multiplier*
2. *Normal Systemwide Model Minimum Day Demand is 51,716 gpm*
3. *Total Model Demands with elevated wholesale customers is 91,957 gpm*
4. *Satisfied Demands assume junction pressure greater than 0 psi*
5. *System Positive Pressure based on number of junctions above 0 psi out of the entire model*

Model Results Figure Index

Fig. 15.1	Hr 0	Fig. 15.5	Hr 8	Fig. 15.9	Hr 16	Fig. 15.13	Hr 24	Fig. 15.17	Hr 40
Fig. 15.2	Hr 2	Fig. 15.6	Hr 10	Fig. 15.10	Hr 18	Fig. 15.14	Hr 28	Fig. 15.18	Hr 44
Fig. 15.3	Hr 4	Fig. 15.7	Hr 12	Fig. 15.11	Hr 20	Fig. 15.15	Hr 32	Fig. 15.19	Hr 48
Fig. 15.4	Hr 6	Fig. 15.8	Hr 14	Fig. 15.12	Hr 22	Fig. 15.16	Hr 36		



Sacrificial Areas
Model Pipes
S4
S7
S8
T2
Storage
Wholesale Customers
Combined RH Tanks
Lake Forest Park Reservoir
Tolt 1 & 2
Foy Standpipe
Bitter Lake Reservoir
Region S8
Region S4
Pipe Closed (7043)
Pipe Closed (7031)
Pipe Closed (7513)
Tolt 1
Tolt 2
Tolt Filtration Plant
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Region S7
Region T2
Magnolia Reservoir
Magnolia Bluff Tank
Volunteer Reservoir
Volunteer Standpipe
Queen Anne Standpipe
Lincoln Reservoir
Tolt Eastside Supply Line
Mercer Island Pipeline
Eastside Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
Pipes Closed (1033, 3033)
One CRPL Pipe Open
West Seattle Reservoir
Cedar Eastside Supply Line
Beverly Park Tank
West Seattle Pipeline
Riverton Reservoir
CRPL 4
Cedar Treatment Clearwell
Combined Soos Reservoirs
Puget Sound
0 1 2 4 Miles
N
ARCADIS
Water Distribution System Seismic Modeling
Transmission - SFZ Event
Case 2075 Model Index



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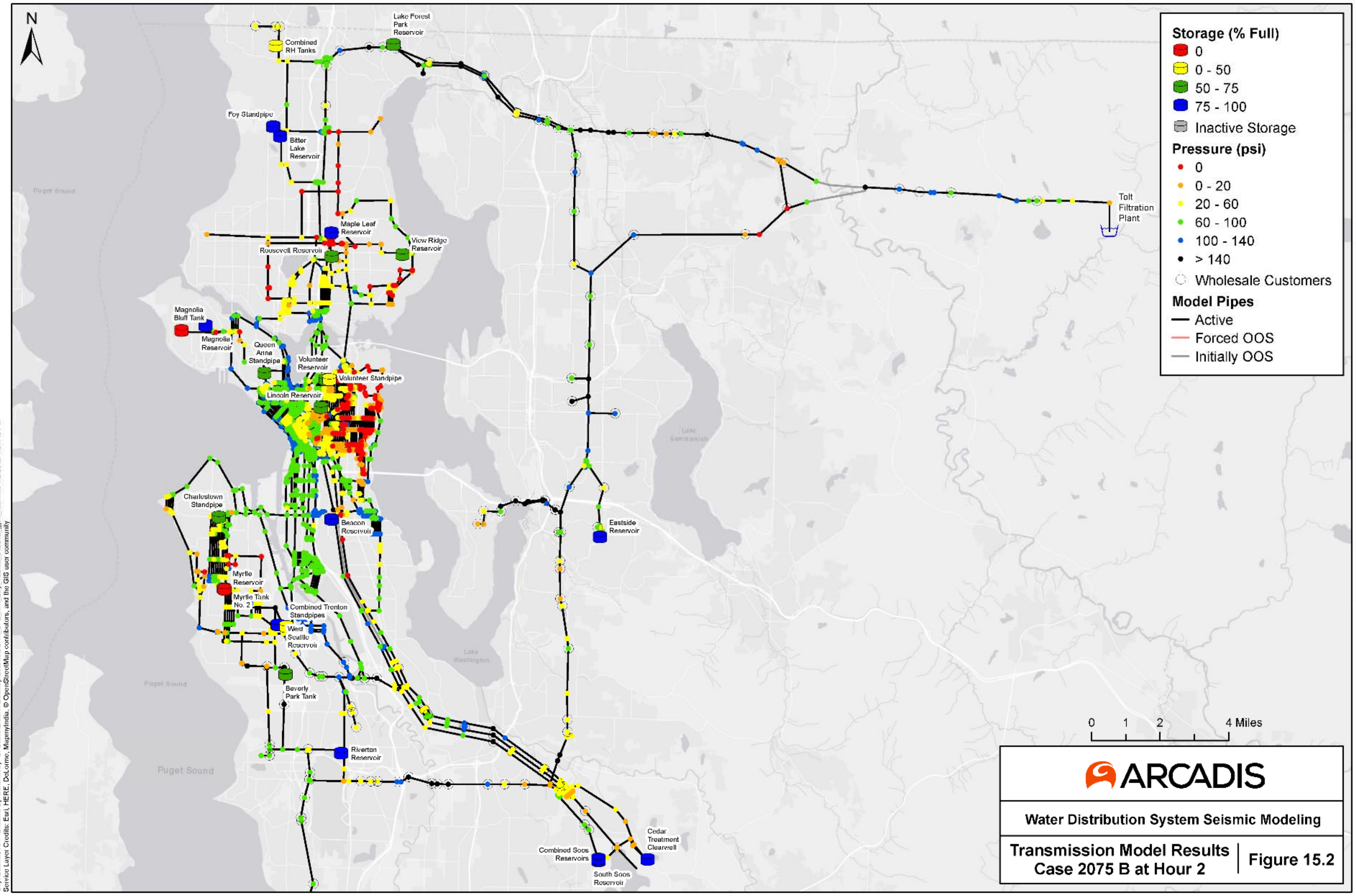

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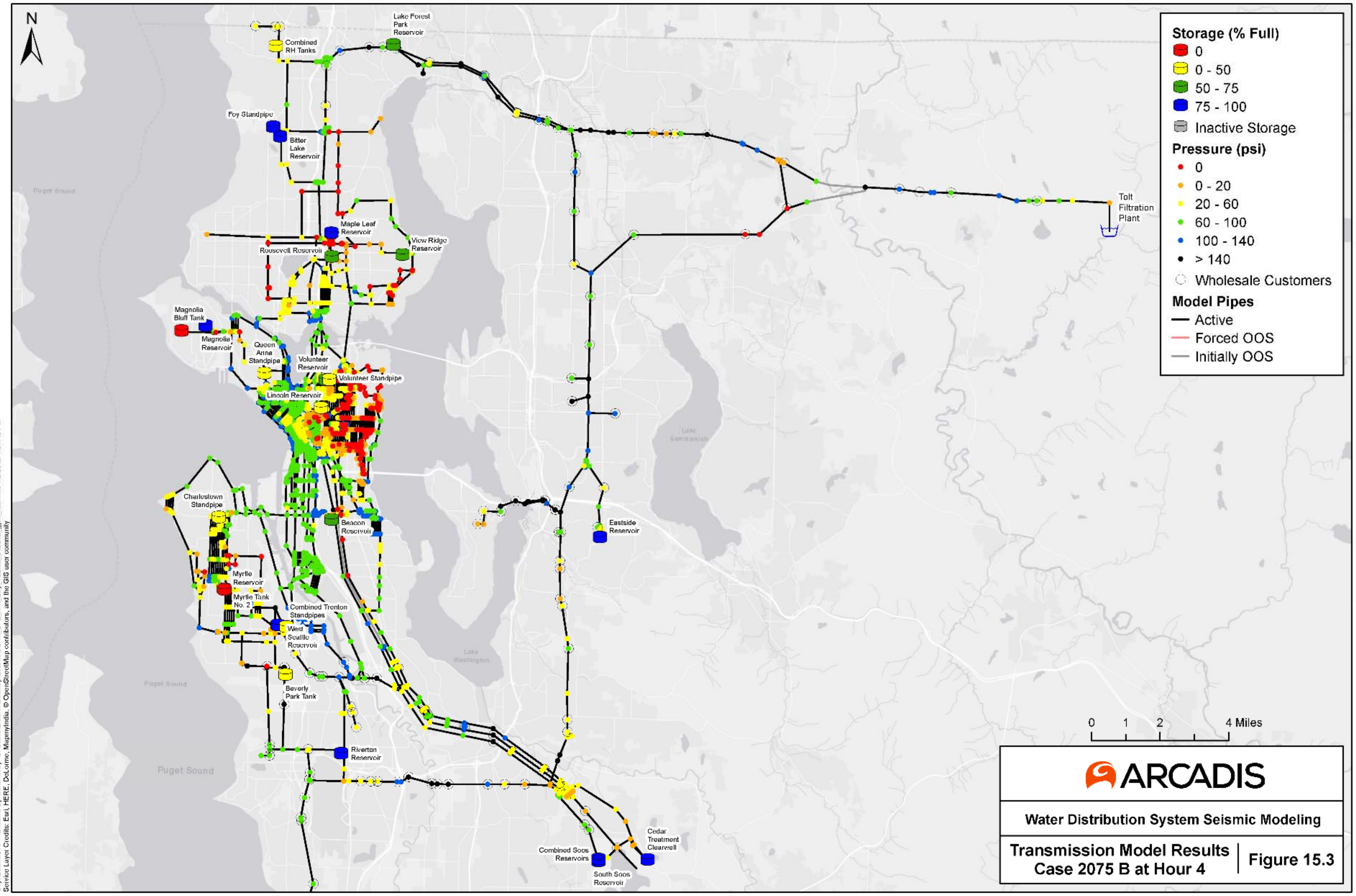
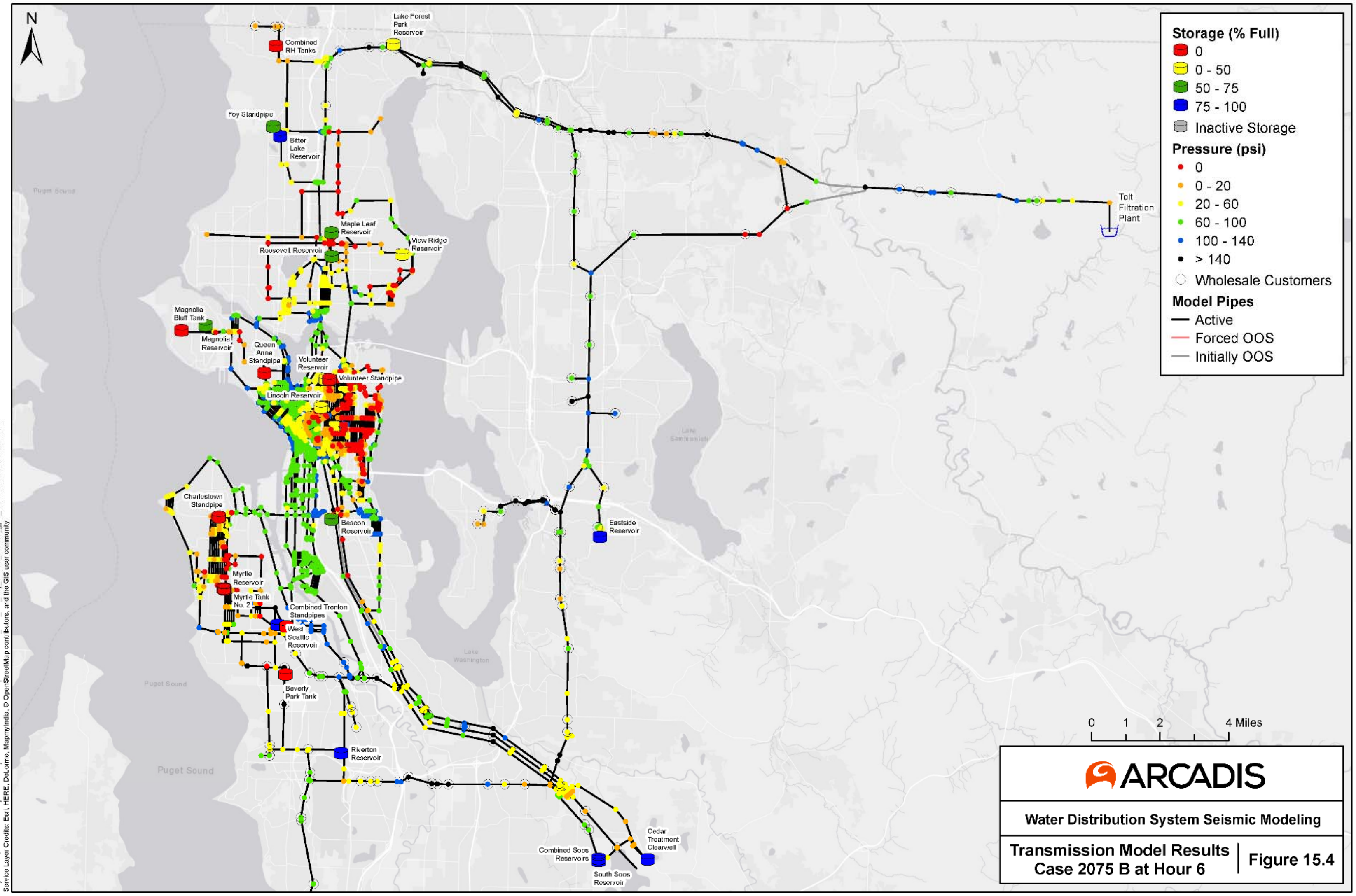
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

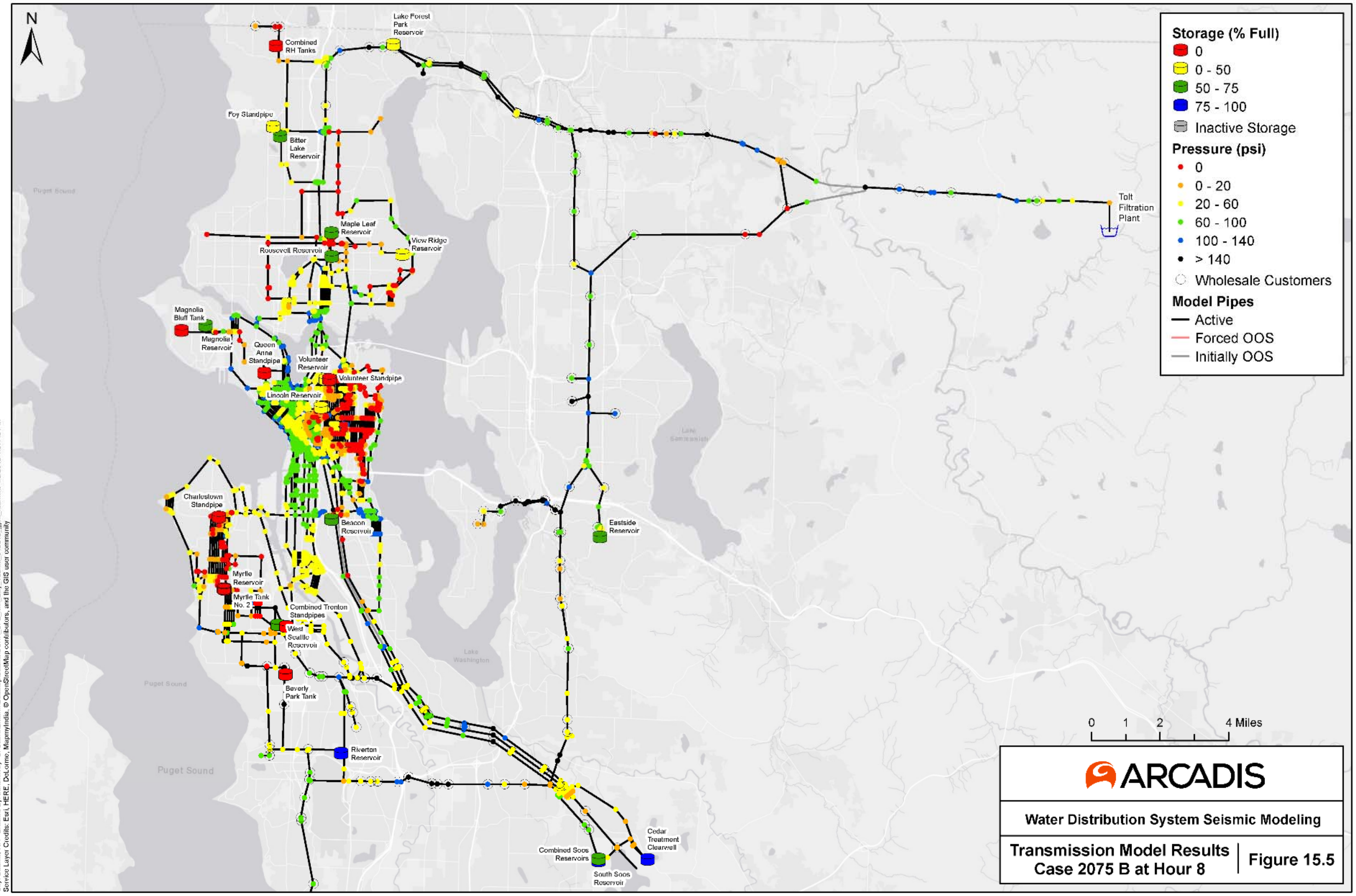


Transmission Model Results Case 2075 B at Hour 4

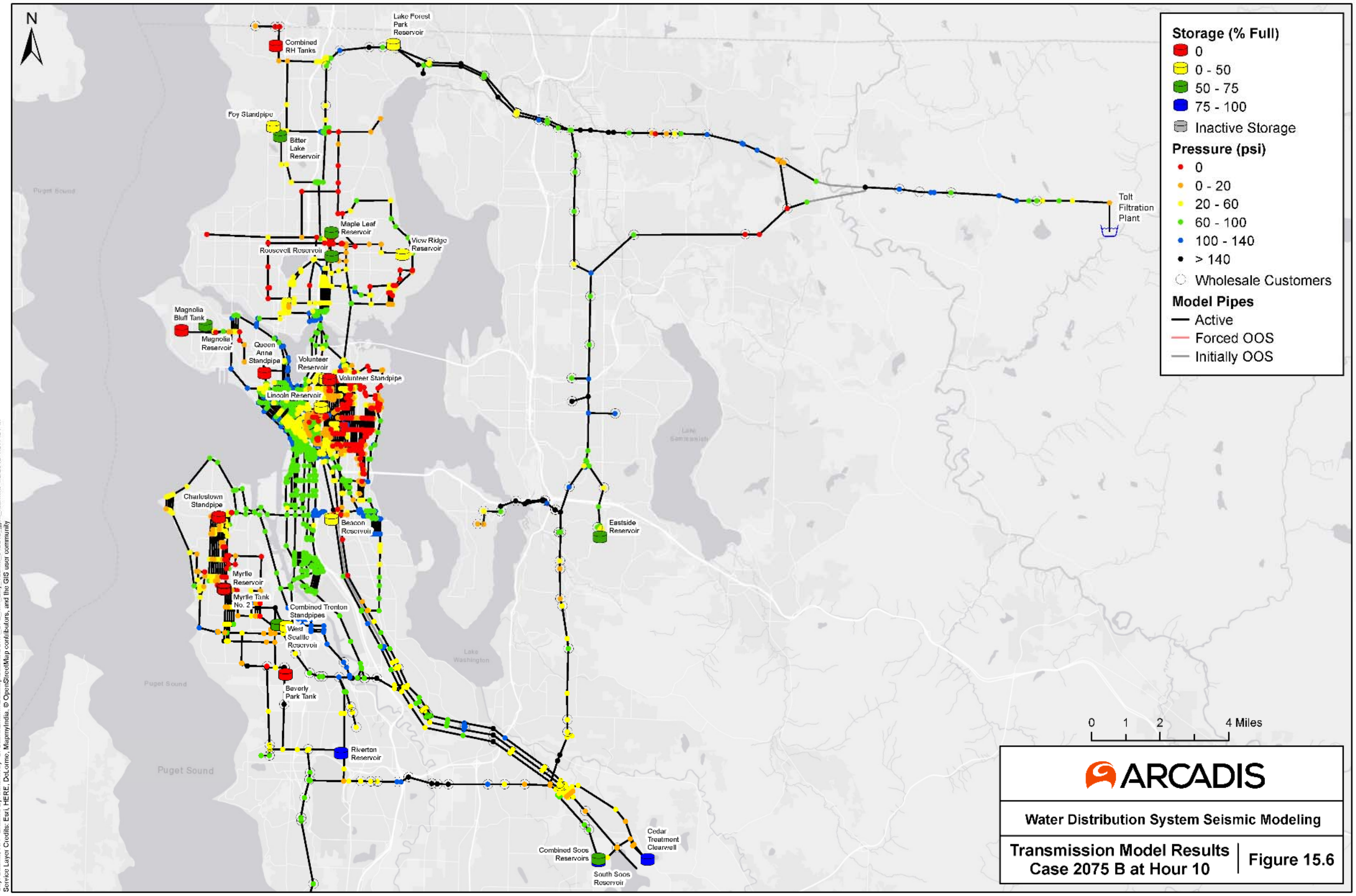
Figure 15.3



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 6
Figure 15.4



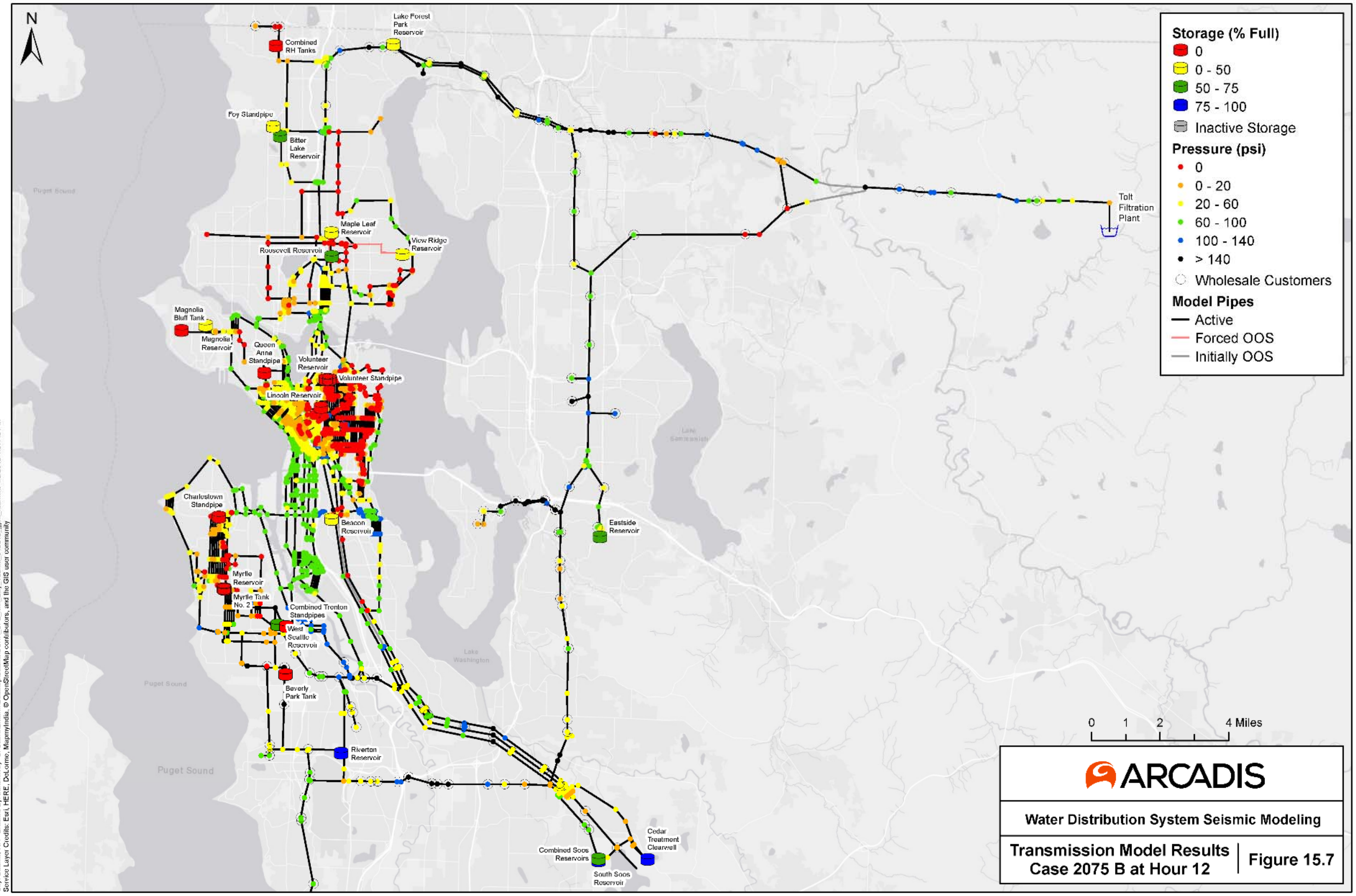
N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 8
Figure 15.5



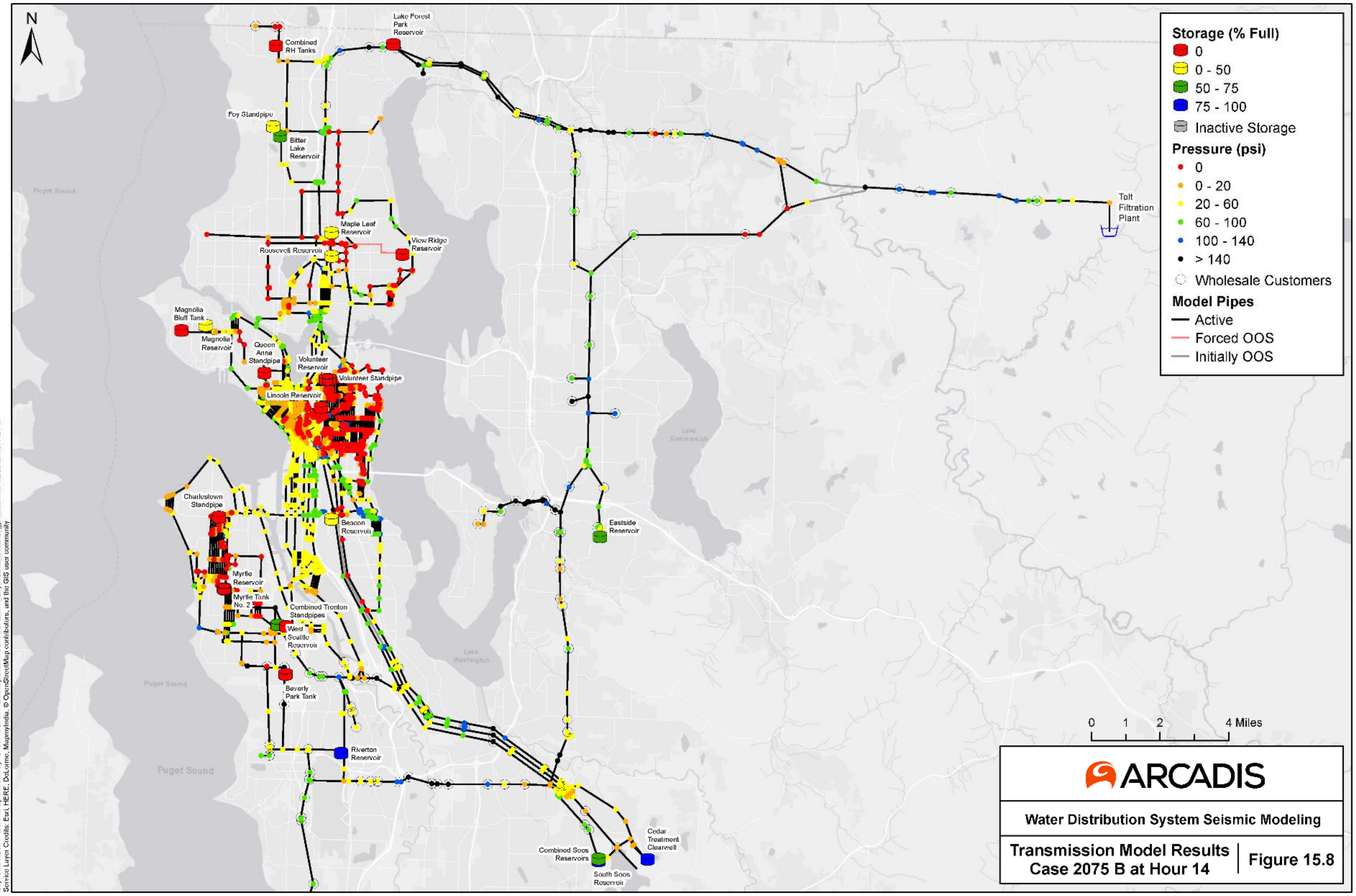
Water Distribution System Seismic Modeling

Transmission Model Results Case 2075 B at Hour 10

Figure 15.6

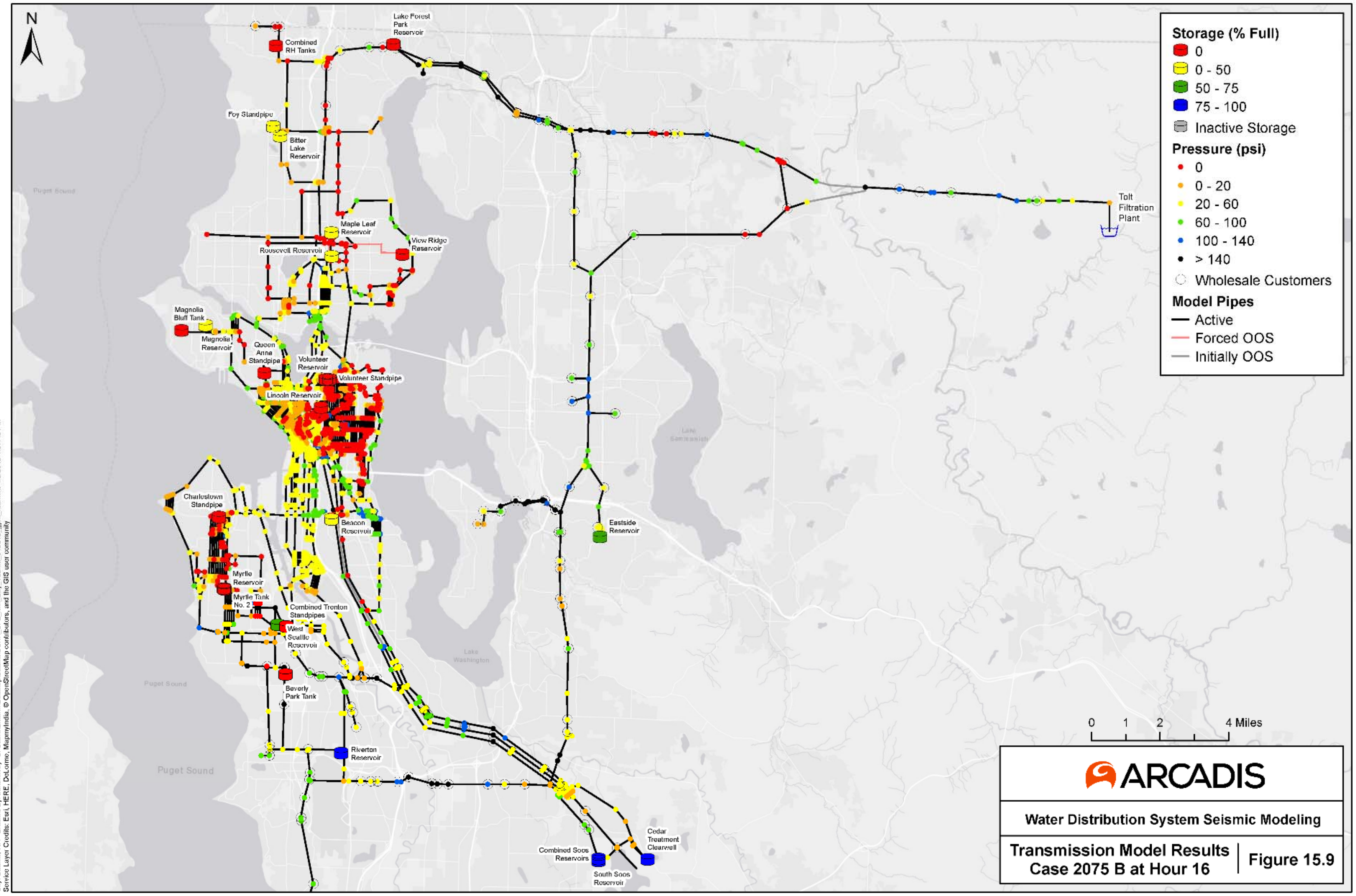


N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 12
Figure 15.7



Water Distribution System Seismic Modeling

Transmission Model Results Case 2075 B at Hour 14 | Figure 15.8



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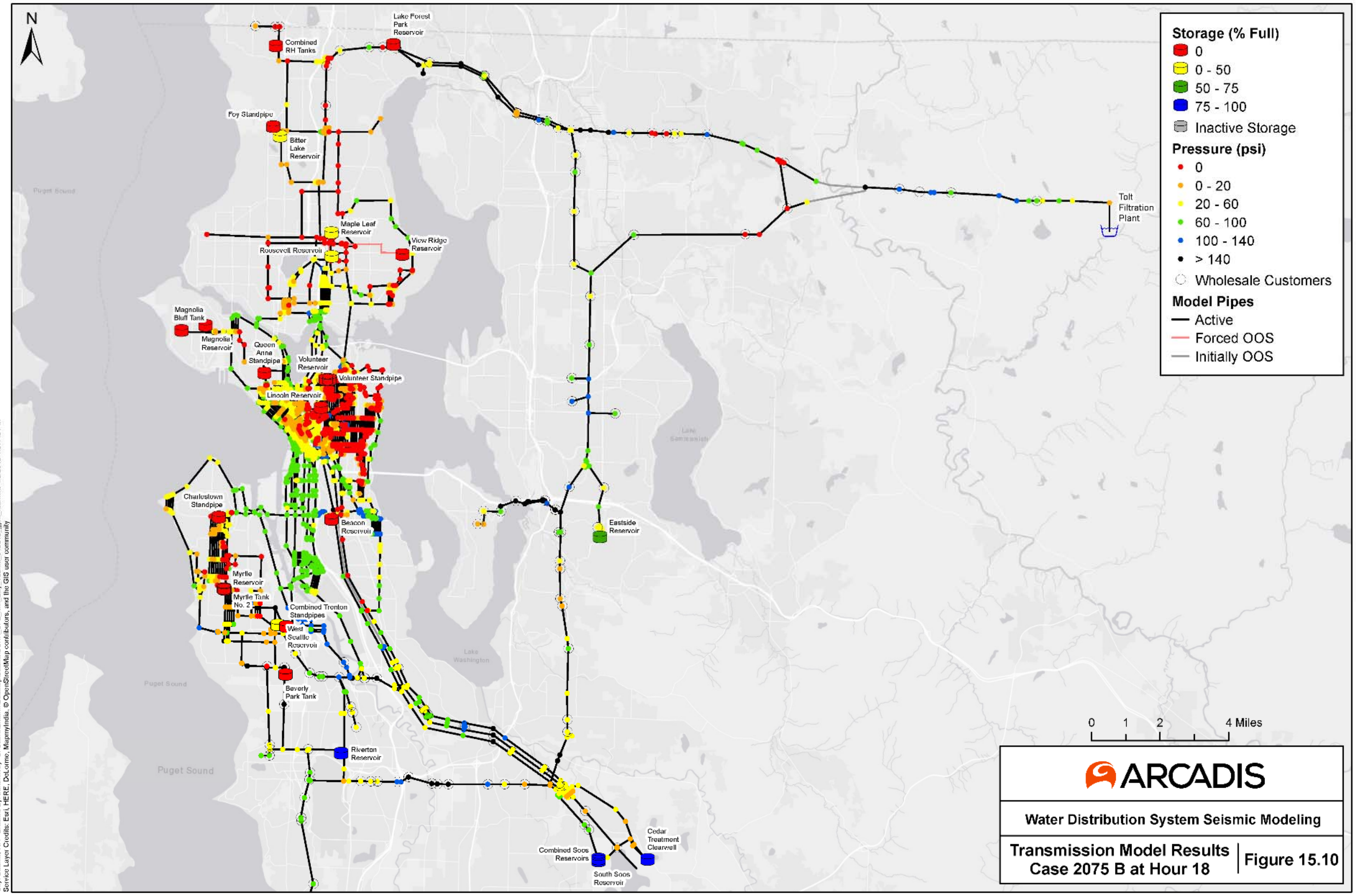
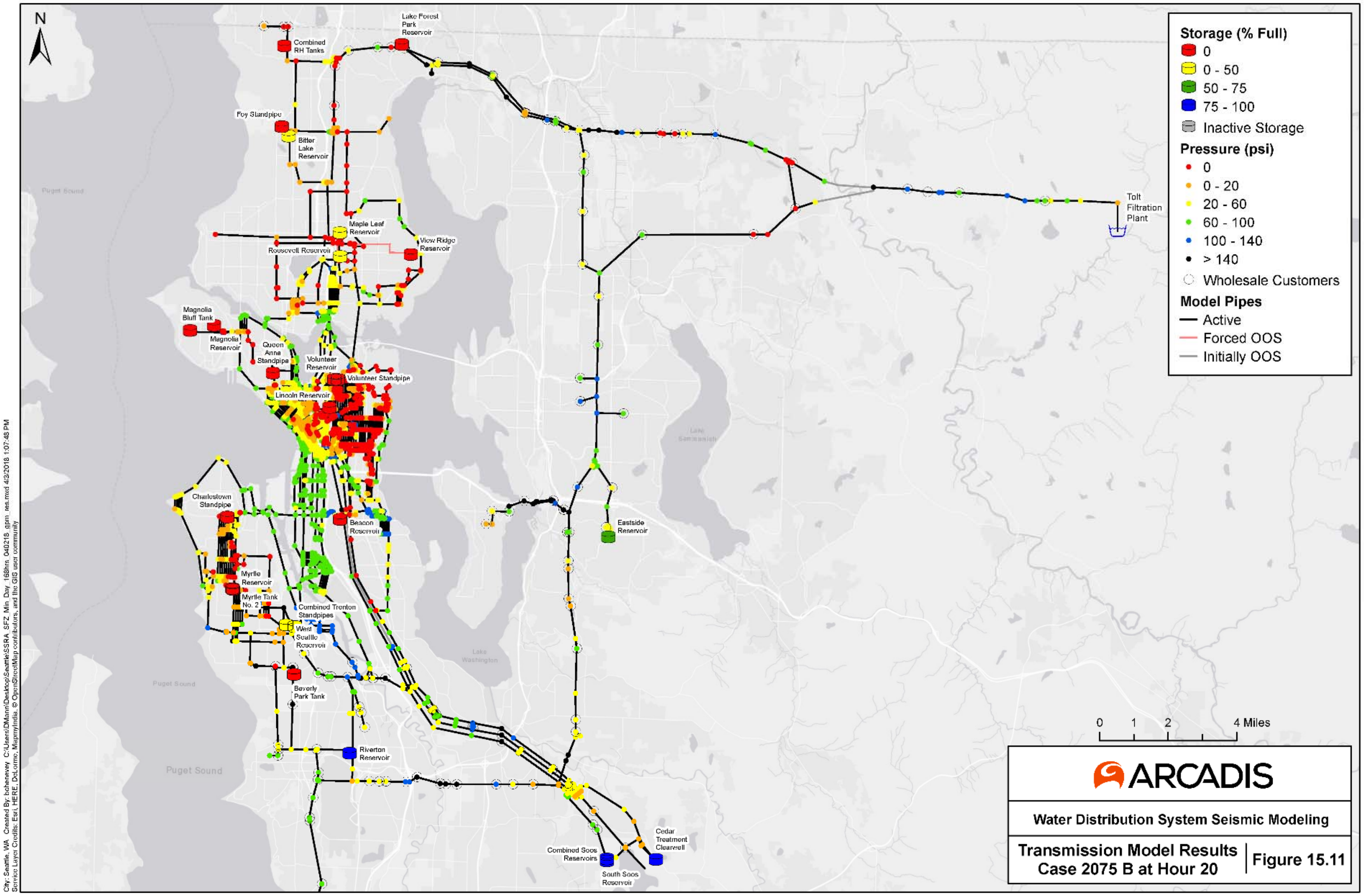
Water Distribution System Seismic Modeling

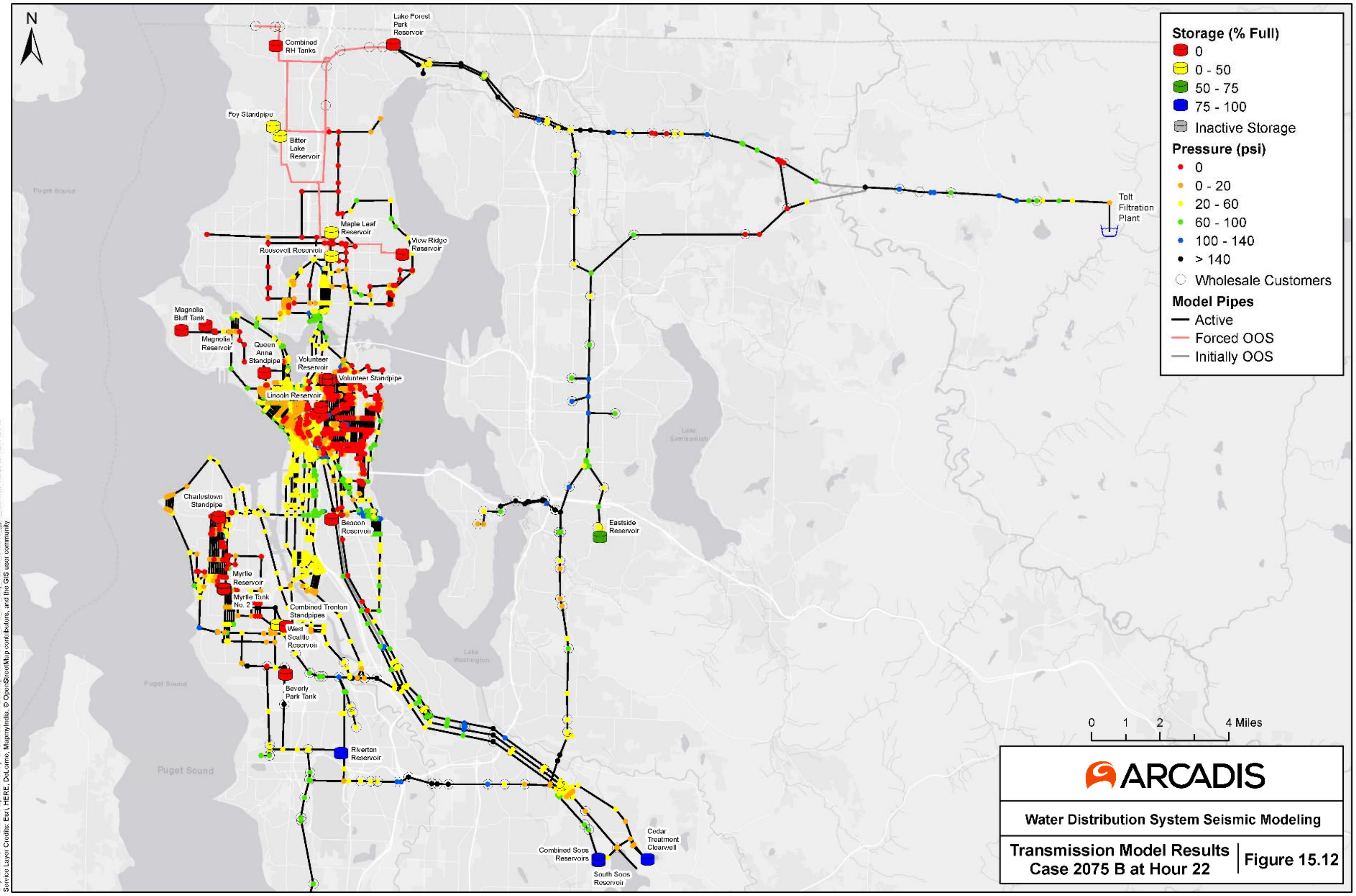
Transmission Model Results
Case 2075 B at Hour 16

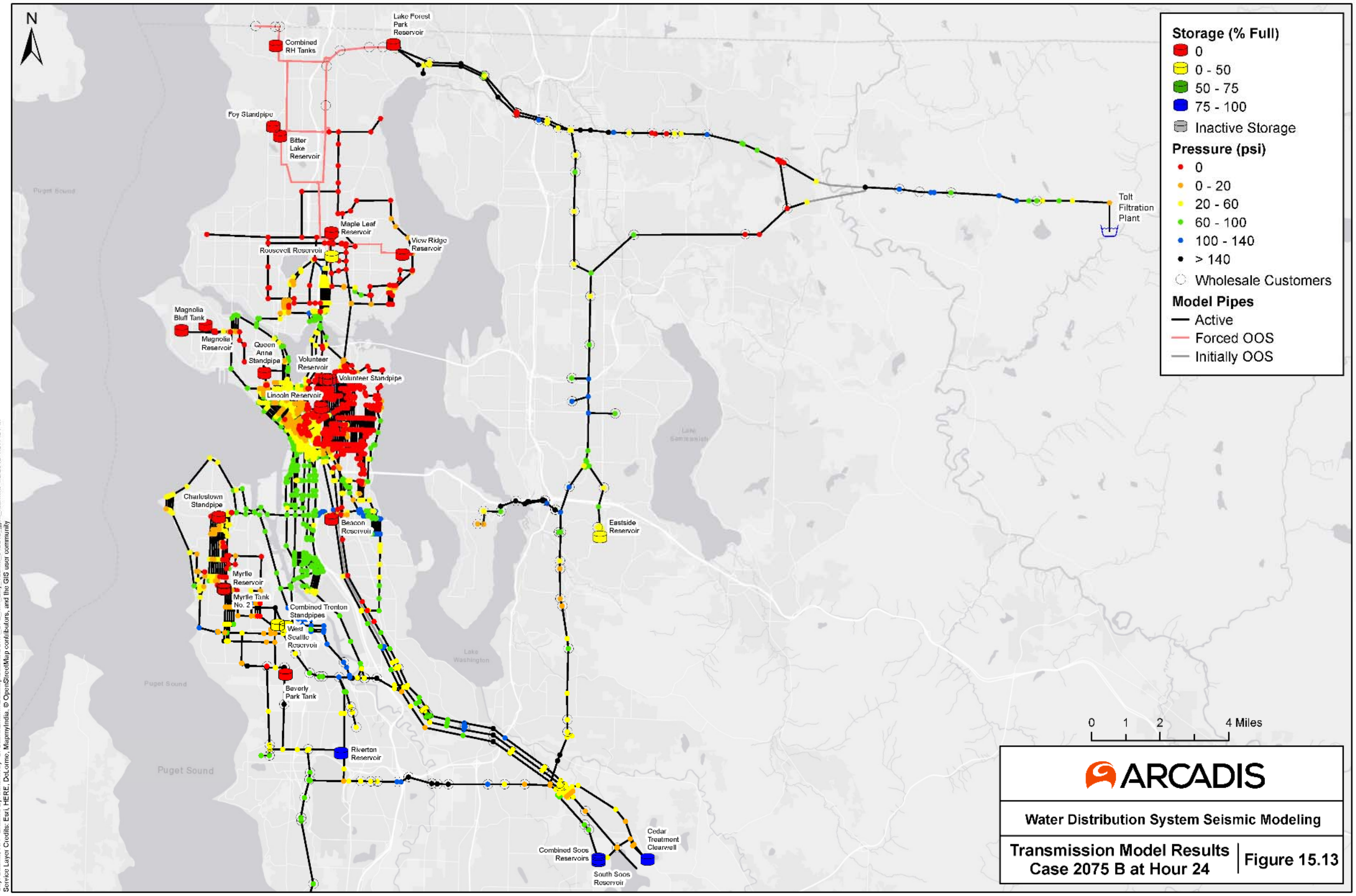
Figure 15.9

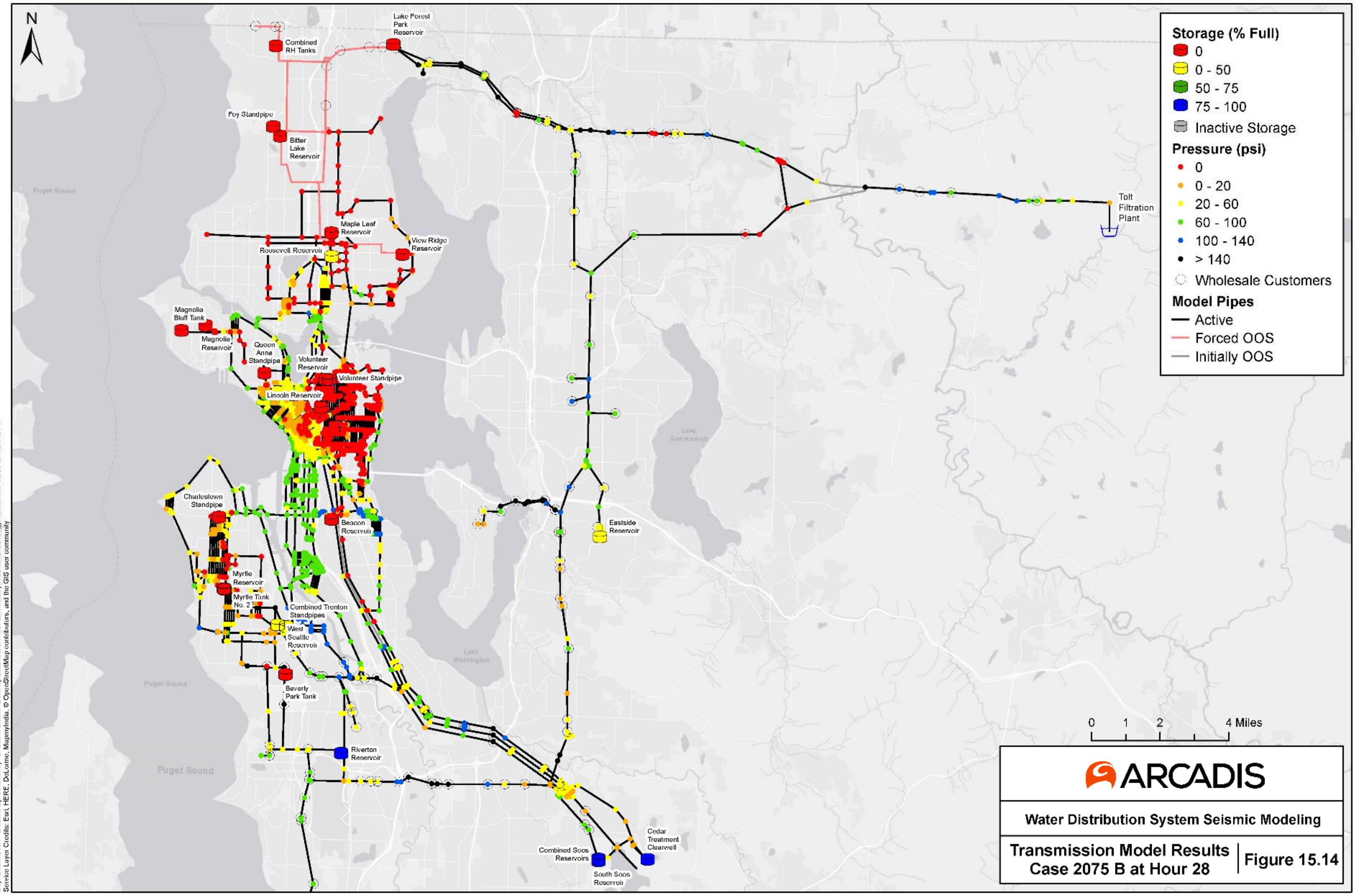

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Combined RH Tanks
Lake Forest Park Reservoir
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 18
Figure 15.10



N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 20
Figure 15.11

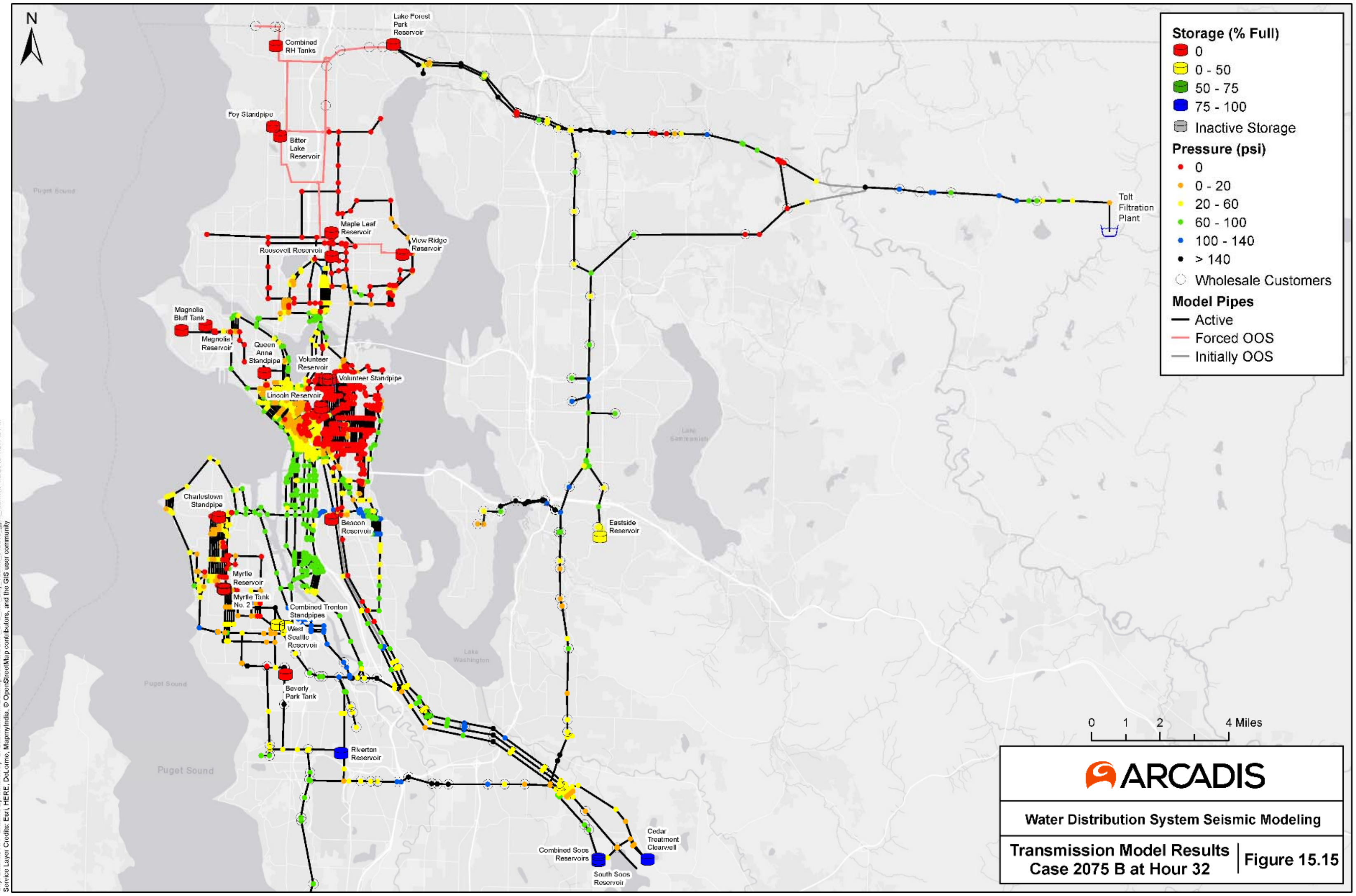

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
Roosevelt Reservoir
View Ridge Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Eastside Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Tolt Filtration Plant
Puget Sound
Lake Washington
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 22
Figure 15.12

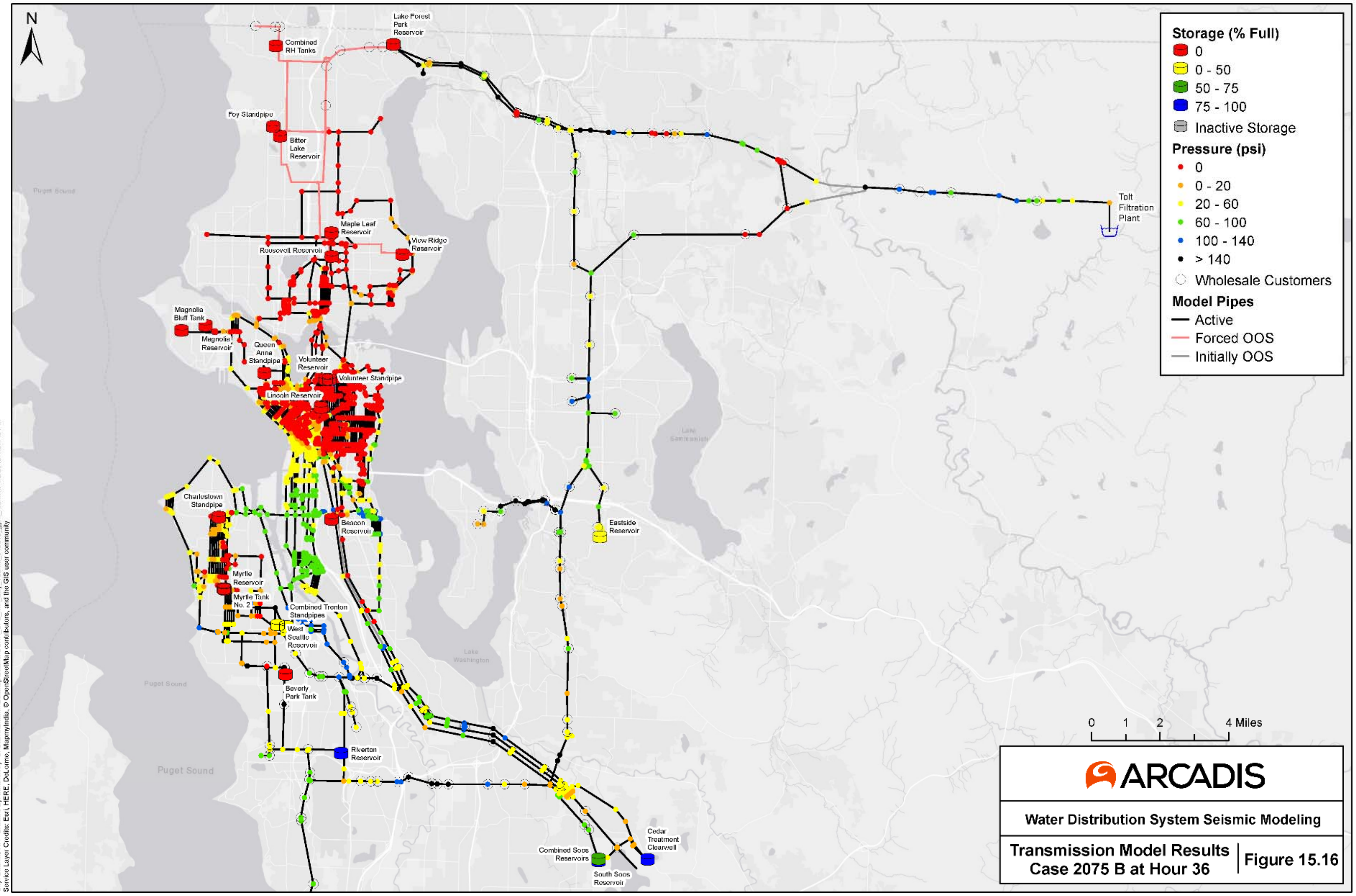

N
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 24
Figure 15.13
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Lake Washington
Lake Sammamish



Transmission Model Results Case 2075 B at Hour 28

Figure 15.14

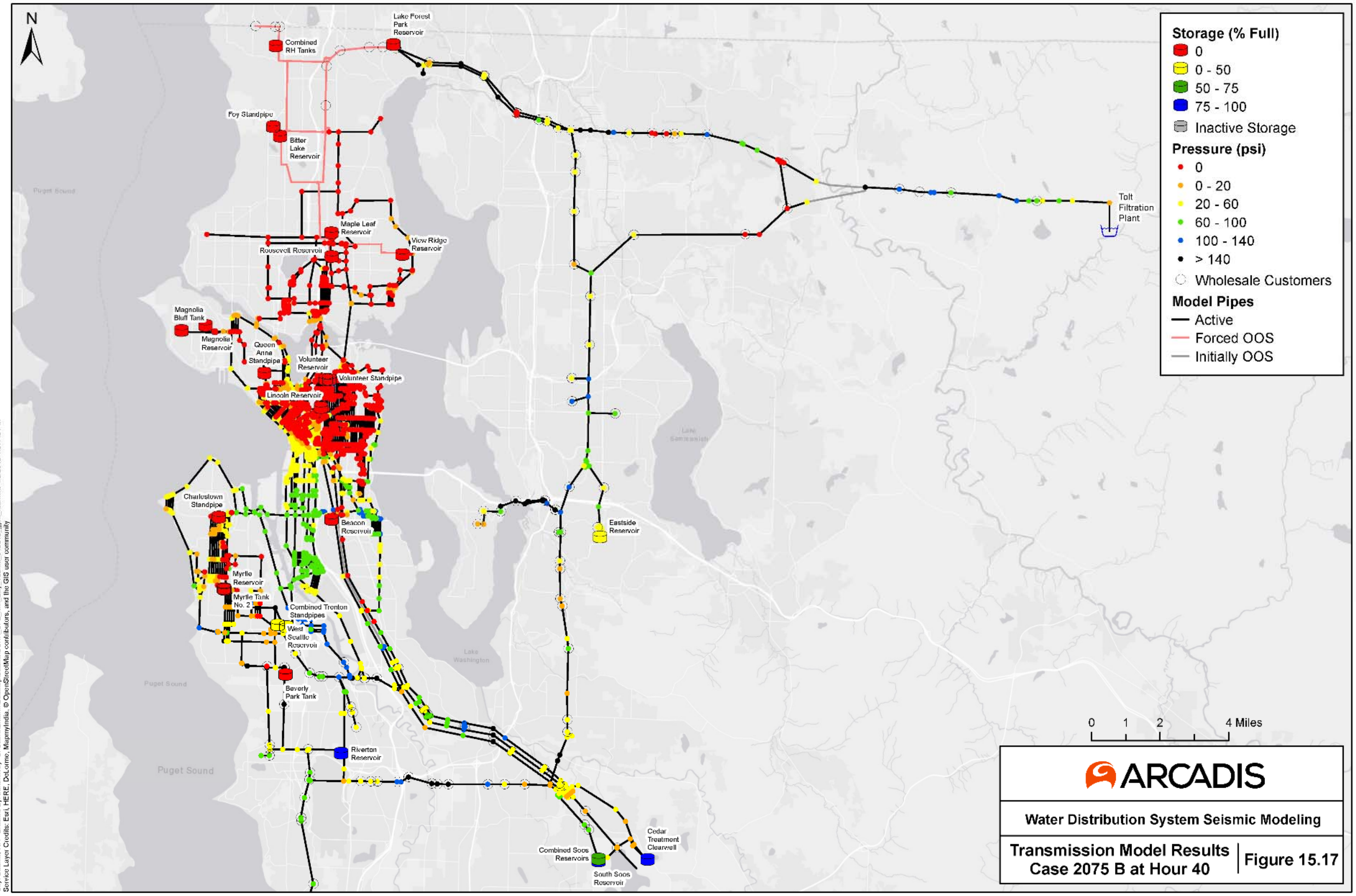

N
Lake Forest Park Reservoir
Combined RH Tanks
Foy Standpipe
Bitter Lake Reservoir
Maple Leaf Reservoir
View Ridge Reservoir
Roosevelt Reservoir
Magnolia Bluff Tank
Magnolia Reservoir
Queen Anne Standpipe
Volunteer Reservoir
Volunteer Standpipe
Lincoln Reservoir
Charlestown Standpipe
Beacon Reservoir
Myrtle Reservoir
Myrtle Tank No. 2
Combined Trenton Standpipes
West Seattle Reservoir
Beverly Park Tank
Riverton Reservoir
Eastside Reservoir
Tolt Filtration Plant
Combined Soos Reservoirs
South Soos Reservoir
Cedar Treatment Clearwell
Puget Sound
Puget Sound
Puget Sound
Lake Washington
Lake Sammamish
Storage (% Full)
0
0 - 50
50 - 75
75 - 100
Inactive Storage
Pressure (psi)
0
0 - 20
20 - 60
60 - 100
100 - 140
> 140
Wholesale Customers
Model Pipes
Active
Forced OOS
Initially OOS
0 1 2 4 Miles
ARCADIS
Water Distribution System Seismic Modeling
Transmission Model Results
Case 2075 B at Hour 32
Figure 15.15



Water Distribution System Seismic Modeling

Transmission Model Results Case 2075 B at Hour 36

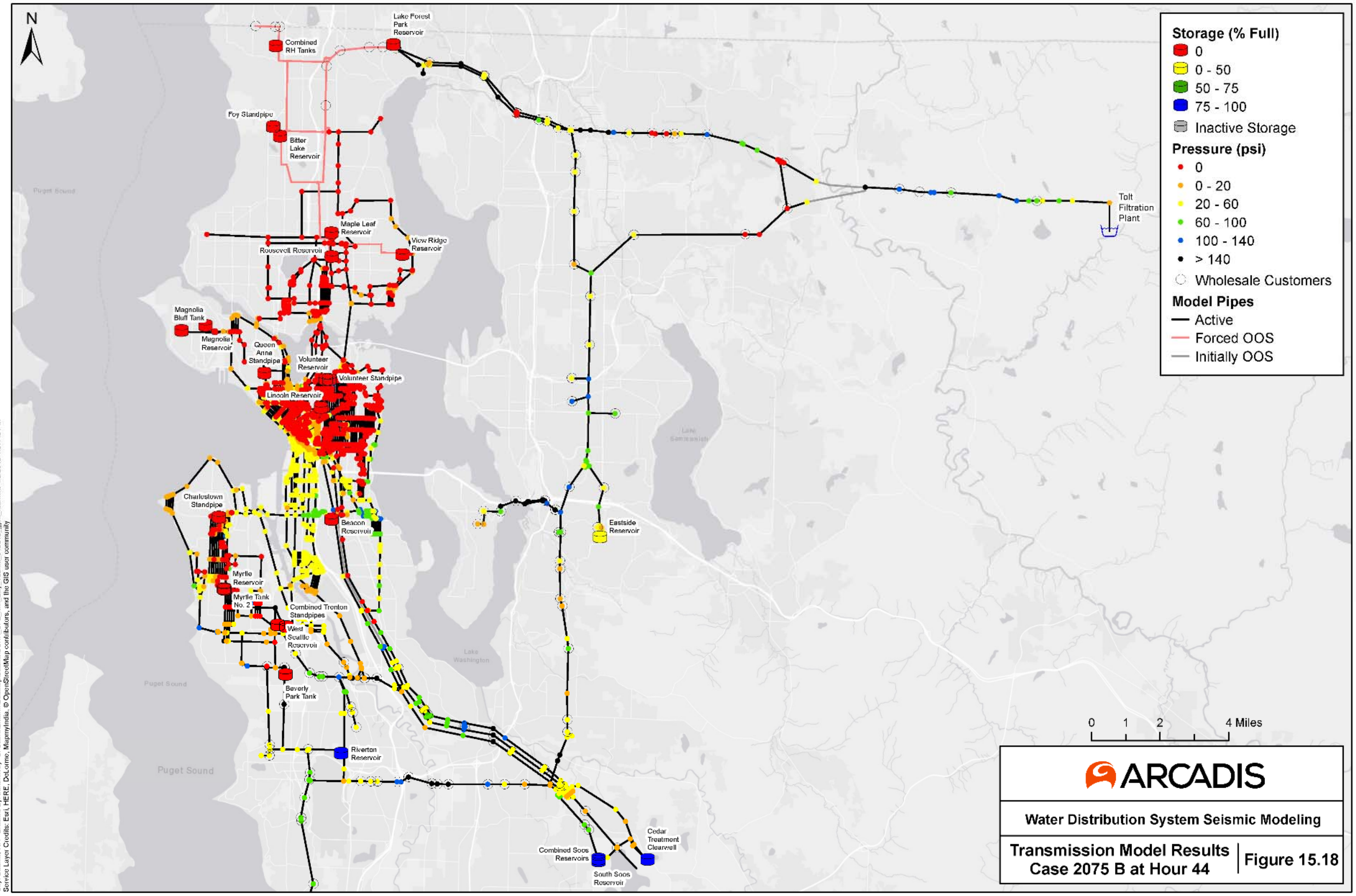
Figure 15.16



Transmission Model Results Case 2075 B at Hour 40

Figure 15.17

City: Seattle, WA Created By: bchenevey C:\Users\DMann\Desktop\Seattle\SSRA_SFZ_Min_Day_168hrs_040218_gpm_res.mxd 4/3/2018 1:07:48 PM
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



ARCADIS

Water Distribution System Seismic Modeling

Transmission Model Results Case 2075 B at Hour 44 | Figure 15.18

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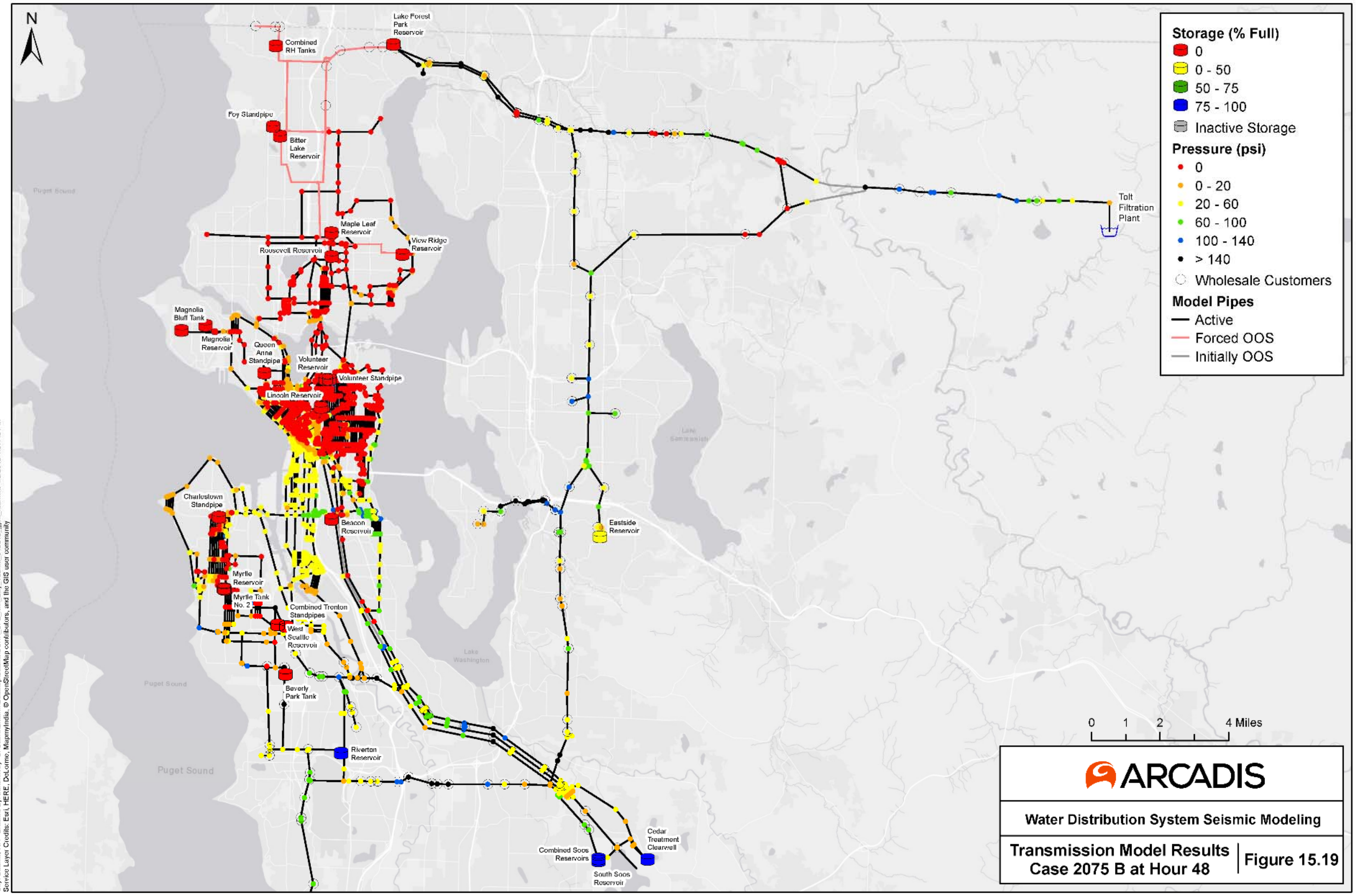

Transmission Model Results
Case 2075 B at Hour 48

Figure 15.19

APPENDIX C – REPRESENTATIVE WATER UTILITY PERFORMANCE GOALS

KEY TO THE TABLE

TARGET TIMEFRAME FOR RECOVERY:

Desired time to restore component to 80–90% operational	G
Desired time to restore component to 50–60% operational	Y
Desired time to restore component to 20–30% operational	R
Current State (90% operational)	X

TARGET STATES OF RECOVERY: WATER & WASTEWATER SECTOR (COAST)											
	Event occurs	0–24 hours	1–3 days	3–7 days	1–2 weeks	2 weeks – 1 month	1–3 months	3–6 months	6 months–1 year	1–3 years	3 + years
Domestic Water Supply											
Potable water available at supply source (WTP, wells, impoundment)				R		Y		G		X	
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational			R	Y	G					X	
Water supply to critical facilities available				R		Y		G		X	
Water for fire suppression—at key supply points			R		Y			G		X	
Water for fire suppression—at fire hydrants						R	Y	G		X	
Water available at community distribution centers/points				R	Y	G	X				
Distribution system operational					R		Y	G			X

Table C-1. Oregon Resilience Plan (2013) Water System Post-Earthquake Recovery Targets for Coastal Communities (Stronger Ground Shaking than Willamette Valley)

KEY TO THE TABLE

TARGET TIMEFRAME FOR RECOVERY:

Desired time to restore component to 80–90% operational	G
Desired time to restore component to 50–60% operational	Y
Desired time to restore component to 20–30% operational	R
Current state (90% operational)	X

TARGET STATES OF RECOVERY: WATER & WASTEWATER SECTOR (VALLEY)											
	Event occurs	0–24 hours	1–3 days	3–7 days	1–2 weeks	2 weeks–1 month	1–3 months	3–6 months	6 months –1 year	1–3 years	3 + years
Domestic Water Supply											
Potable water available at supply source (WTP, wells, impoundment)		R	Y		G			X			
Main transmission facilities, pipes, pump stations, and reservoirs (backbone) operational		G					X				
Water supply to critical facilities available		Y	G				X				
Water for fire suppression—at key supply points		G		X							
Water for fire suppression—at fire hydrants				R	Y	G			X		
Water available at community distribution centers/points			Y	G	X						
Distribution system operational			R	Y	G				X		

Table C-2. Oregon Resilience Plan (2013) Water System Post-Earthquake Recovery Targets for Willamette Valley Communities (Lower Ground Shaking than Oregon Coast)

KEY TO THE TABLE

TARGET TIMEFRAME FOR RECOVERY:

Operational (time it ought to take to restore component to 80–90% operational):	
TIME NEEDED FOR RECOVERY TO 80–90% OPERATIONAL GIVEN CURRENT CONDITIONS:	**X**
TIME NEEDED FOR RECOVERY TO 80–90% OPERATIONAL IN LIQUEFACTION ZONES GIVEN CURRENT CONDITIONS:	**L**
TIME NEEDED FOR RECOVERY TO 80–90% OPERATIONAL IN NON-LIQUEFACTION ZONES GIVEN CURRENT CONDITIONS:	**NL**

TARGET STATES OF RECOVERY: WASHINGTON'S UTILITIES SECTOR

	Event occurs	0–24 hours	1–3 days	3–7 days	1 week–1 month	1–3 months	3 months–1 year	1–3 years	3+ years
Domestic water supply									
Supply & transmission pipes				NL			L		
Distribution pipes					NL		L		
Wastewater systems									
Treatment facilities						NL	L		
Sewer pipes						NL		L	
Flood control									
Dams						X			
Levees								X	
Electricity									
Transmission								X	
Distribution, 60% restored					X				
Distribution, 70% restored						X			
Distribution, >70% restored							X		
Natural Gas									
Transmission			NL		L				
Distribution, 40% restored					X				
Distribution, 90% restored						X			
Petroleum									
Refineries & transmission								X	
Distribution						X			
Information and communication technology						X			

Table C-3. Resilient Washington State (2012) Lifeline Post-Earthquake Recovery Targets

Service Category		Probable Earthquake
General	1	Minimal secondary damage and risk to the public
	2	Limit extensive damage to system facilities
	3	All water introduced into the distribution system minimally disinfected
	4	All water introduced into the distribution system fully treated
Fire Service	5	Sufficient portable pumps and hose to provide limited fire service in all areas
	6	All areas have minimal fire service (one reliable pumping plant and reservoir)
	7	High risk areas have improved fire service (all facilities reliable, minimum fire reserves)
	8	Normal service to all hydrants within 20 days
Hospitals and Disaster Centers	9	Minimum service to affected area within 1 day (water available via distribution system near each facility)
	10	Impaired service to affected area within 3 days (water available via distribution system to each facility, possibly at reduced pressures)
Domestic Users	11	Potable water via distribution system or truck within 1 day
	12	Impaired service to affected area within 3 days (water available via distribution system to each domestic user, possibly at reduced pressures)
Commercial, Industrial and Other Users	13	Impaired service to affected area within 3 days (water available via distribution system to each commercial or industrial user, possibly at reduced pressures)

Table C-4. East Bay Municipal Utility District (EBMUD) Post-Earthquake Performance Goals for A "Probable" Earthquake (e.g., M6 Hayward Fault Event within the EBMUD Service Area or Larger Event Outside the EBMUD Service Area) (Eidinger and Davis 2012)

Service Category		Maximum Earthquake
General	1	Minimal secondary damage and risk to the public
	2	Limit extensive damage to system facilities
	3	All water introduced into the distribution system minimally disinfected
	4	All water introduced into the distribution system fully treated
Fire Service	5	Sufficient portable pumps and hose to provide limited fire service in all areas
	6	All areas have minimal fire service (one reliable pumping plant and reservoir)
	7	High risk areas have improved fire service (all facilities reliable, minimum fire reserves)
	8	Normal service to all hydrants within 100 days
Hospitals and Disaster Centers	9	Minimum service via distribution system or truck within 3 days
	10	Minimum service within 10 days (water available via distribution system near each facility)
	11	Impaired service within 30 days (water available via distribution system to each facility, possibly at reduced pressures)
Domestic Users	12	Potable water at central locations for pickup within 3 days
	13	Minimum service to 70% of customers within 10 days
Commercial, Industrial and Other Users	14	Potable water at central locations for pickup within 1 week
	15	Minimum service to 70% of customers within 10 days
	16	Impaired service to 90% of customers within 30 days (water available via distribution system to 90% of commercial or industrial users, possibly at reduced pressures)

Table C-5. East Bay Municipal Utility District (EBMUD) Post-Earthquake Performance Goals for A "Maximum" Earthquake (e.g., A Hayward Fault Event Where the Fault Ruptures Along The Entire Length Within the EBMUD Service Area) (Eidinger and Davis 2012)

Service Category		Probable Earthquake
General	1	Minimal secondary damage and risk to the public
	2	Limit extensive damage to system facilities
	3	All water introduced into the distribution system minimally disinfected
Fire Service	4	Provide 100% of average winter level flows to customer meters within 4 hours after earthquake. (Tentative goal for large customers)
	5	Provide 100% of average winter level flows to all customer meters within 3 days after earthquake. (Tentative goal for large customers)
Domestic Water Service	6	Potable water via truck or accessible locations within 1 day to meet minimum consumption needs (1 gallon per person per day)
	7	Impaired service within 3 days
	8	Normal service within 20 days
Raw Water Service	9	Impaired service within 3 days
	10	Normal service within 20 days

Minimally Disinfected	Chlorination or better.
Impaired Service	Provide water (adequate to meet winter time demands), possibly at lower pressure than normal.
Normal service	Provide water at the same level of reliability as under "normal" pre-earthquake co nditions.

Figure C-6. Humboldt Bay Municipal Water District Post-Earthquake Performance Goals for a Probable Earthquake (Eidinger and Davis 2012)

Service Category		Maximum Earthquake
General	1	Minimal secondary damage and risk to the public
	2	Limit extensive damage to system facilities
	3	All water introduced into the distribution system minimally disinfected
Fire Service	4	Provide 50% of average winter level flows to customer meters within 4 hours after earthquake. (Tentative goal for large customers)
	5	Provide 100% of average winter level flows to all customer meters within 3 days after earthquake. (Tentative goal for large customers)
Domestic Water Service	6	Potable water via truck or accessible locations within 1 day to meet minimum consumption needs (1 gallon per person per day)
	7	Impaired service within 7 days
	8	Normal service within 60 days
Raw Water Service	9	Impaired service within 7 days
	10	Normal service within 60 days

Minimally Disinfected	Chlorination or better.
Impaired Service	Provide water (adequate to meet winter time demands), possibly at lower pressure than normal.
Normal service co	Provide water at the same level of reliability as under "normal" pre-earthquake nditions.

Figure C-7. Humboldt Bay Municipal Water District Post-Earthquake Performance Goals for a Maximum Earthquake (Eidinger and Davis 2012)

Level	Hazard Return Period Criteria	Target Water System Performance
1	100 years	Limited damage to water system, no casualties, few to no water service losses. All customer services operational within about 3 days.
2	500 years	Life safety and property protection. All customer services operational within about 20 days, except water quantity; rationing may extend up to 30 days.
3	2500 years[1]	Life safety and property protection. All customer services operational within about 30 days, except water quantity; rationing may extend up to 60 days.
4	> 2500 years up to about 10,000 years	Life safety and property protection. All customer services operational within about 45 days, except water quantity; rationing may extend up to 12 months.

1 – Highly active faults such as the San Andreas Fault have great earthquakes of $M_w > 7.8$ within these return periods, for which the performance criteria are proposed to meet Level 4.

Table C-8. Los Angeles Department of Water and Power Preliminary/Draft Post-Earthquake Performance Criteria (Davis 2017)

APPENDIX D – DRAFT SPU SEISMIC DESIGN STANDARDS FOR NEW PIPE

Scope

This standard applies to new watermain construction, including new pipelines that are replacing existing pipelines. Existing watermains need not adhere to these standards unless they are rehabilitated or replaced.

Adoption and Revisions/Updates

This draft standard will form the framework for SPU's seismic design standards for new watermains. Before these standards can be officially adopted by SPU, they will be reviewed by SPU design engineers and operations staff. The standards will be periodically updated to reflect the American Society of Civil Engineers (ASCE) Manual of Practice (MOP) on seismic design guidelines for water and wastewater pipelines that is currently being developed, seismic hazard mapping changes that occur in the SPU transmission and distribution area, and new earthquake resistant pipe systems that are being developed.

Definitions

Primary Backbone Pipelines–Transmission pipelines that convey water from the Tolt Reservoir or Lake Youngs Treatment Plant to the terminal reservoirs. Primary Backbone Pipelines are identified in Figures 1 and 2.

Secondary Backbone Pipelines–Transmission
pipelines that convey water from the terminal reservoirs to distribution reservoirs or large service areas. Because Lake Youngs can supply the Cedar system for four weeks, the transmission pipelines from the Landsburg Diversion to Lake Young are defined as secondary backbone pipelines. Secondary Backbone Pipelines are identified in Figures 1 and 2.

Hospital/Critical Facility Watermains–Watermains that are needed to supply hospitals or other critical facilities that must remain operational after an earthquake. Hospital/Critical Facility Watermains are identified in Figure 2.

Fire-fighting Mains–Mains needed to supply water to within 2,500 feet of anywhere in the City of Seattle. Fire-fighting mains are identified in Figure 2.

Ordinary Mains–All watermains that are not classified as backbone, hospital/critical facility or firefighting mains.

Permanent Ground Displacement (PGD)-Susceptible Area – Those areas (see Figures 1 and 2 that are

1. Identified by Palmer et al. (2004) as having a high- or moderate-to-high liquefaction susceptibility or peat area, or

2. Defined by the Seattle Department of Construction and Inspection to be in a Known or Potential Slide Area, or
3. Defined as a King County Landslide Hazard Area, or
4. Defined as a Washington Division of Geology and Earth Resources Landslide Area.

If a geotechnical investigation shows that PGD is possible along the alignment, even though the alignment is not within one of the PGD-susceptible areas identified in Figures 1 or 2, then that pipeline shall be considered to be in a PGD-susceptible area. Alternatively, if a geotechnical investigation shows that the pipeline alignment is not susceptible to PGD, even though the alignment lies within a PGD-susceptible area identified on Figures 1 or 2, the pipeline may be designed as if it does not lie in a PGD-susceptible area.

Seattle Fault Zone–That area defined by Pratt et al. (2015) as adopted by Lettis Consultants International, Inc. (2016) as being in Zone A or Zone B as depicted in Figure 1.

SPU Intense Ground Shaking Region–The area within the SPU transmission and distribution region where the 0.02 probability of exceedance in 50-year ground motions are greater than or equal to 0.6g (see Figure 2).

SPU Watermain Seismic Design and Construction Requirements

The level of analysis and performance required for watermain design and construction shall be in accordance with the watermain criticality and earthquake hazard exposure as defined in Table 1. Primary and secondary backbone pipelines, hospital/critical facility and firefighting mains are identified in Figures 1 and 2. For any pipeline, if a site-specific analysis shows a lesser level of design than that stipulated by Table 1 is adequate, then that pipeline need only be designed in accordance with the design indicated by the site-specific analysis.

Table 1. Minimum Watermain Design and Construction Analysis and Performance Requirements

Watermain Class/Criticality	PGD Area	Seattle Fault Zone or SPU Intense Ground Shaking Region	All Other Areas
Ordinary	Performance Specification 1	Performance Specification 2	No seismic requirements
Hospital/Critical Facility and Fire Fighting Mains	Performance Specification 1	Performance Specification 1	Performance Specification 1
Secondary Backbone	Site-specific analysis	Site-specific analysis	Performance Specification 1
Primary Backbone	Site-specific analysis	Site-specific analysis	Site-specific analysis

Performance Specification 1 Requirements

To meet the requirements for Performance Specification 1, pipelines must meet the following ductility and strength requirements:

1) Segmented Ductile Iron Pipelines

Axial Elongation: 1% Minimum Axial Elongation or Shortening.

Axial Pullout Strength: 17,130 pounds per inch diameter

Deflection: 5 degrees of deflection must be provided at each joint per 20-foot segment. Prorate for shorter or longer segment lengths. Maximum segment length is 30 feet.

Segmented pipeline systems that meet the Performance Specification 1 requirements include, but are not limited to

- Kubota Genex Earthquake Resistant Ductile Iron Pipe
- American Pipe Earthquake Joint Pipe

2) Continuous Pipelines

a) Welded Steel Pipelines with Butt-Welded Joints –
Meet the requirements of AWWA C200 and

$$\frac{D^2}{12t} \leq 537$$

Where D = the pipe diameter in inches

t = the pipe wall thickness in inches

b) HDPE Pipelines – Meet the requirements of AWWA C906 and ASTM F2620.

Pipeline Backfill/Bedding: Pipe backfill and bedding shall be as specified in Standard Plan 350 of Seattle Standard Plans for Municipal Construction. The use of Control Density Fill or other backfill/bedding that could restrict pipe movement is not permitted.

Performance Specification 2 Requirements

The following pipelines are permitted in Performance Specification 2 areas:

1) Restrained joint ductile iron pipe that conforms to the City of Seattle Standard Specifications and Plans. Additionally, for restrained joint ductile iron pipe that is being restrained only to address seismic concerns, Series 1100 MegaLug restrained joints are acceptable.
2) Welded steel pipe joint with either lap or butt welds
3) HDPE pipe that meets the requirements of AWWA C906 and ASTM F2620

4) Restrained joint, molecularly oriented polyvinyl chloride pipe (PVC O) that meets the requirements of AWWA C909.

Site-specific analysis:

The site-specific analysis shall meet the following minimum requirements

1. Geotechnical hazards shall be identified and evaluated along the pipeline alignment.
    a. Geotechnical hazards shall be consistent with those hazards that would occur from 0.02 probability of exceedance in 50 years (2475 average return interval) ground motions.
    b. Geotechnical hazards shall include transient seismic wave propagation/ground shaking hazards and PGD hazards.
2. The pipeline shall be designed and constructed to resist and accommodate the forces and ground motions/displacements along the alignment determined in Step 1. The following criteria must be met:
    a. The pipeline shall remain operable during and after the seismic event.
    b. Inelastic behavior, possibly requiring eventual repair or replacement, is allowable providing the pipeline can remain operable until the post-earthquake emergency conditions have passed.
    c. The larger of either the mean or medium values of the estimated geotechnical hazards (e.g., permanent ground displacement, peak ground velocity, etc.) shall be used in the analysis.
    d. Pipe material and system properties will be as specified by the appropriate ASTM standard with a factor of safety equal to 1.0.

No seismic requirements: New pipelines need only meet SPU non-seismic specific requirements.

Hydrants

For hydrant runs in PGD areas, accommodation shall be made within 10 feet of the hydrant connected to allow for a minimum of five degrees of rotation and two inches of expansion or contraction between the main and hydrant piping. Hydrant connection piping shall be restrained joint ductile iron, welded joint welded steel or HDPE with thermally fused joints.

Services

Services shall be protected by a fabricated steel sleeve that is connected to a semirigid sleeve as shown in Figure 3. The sleeves shall allow the service to move 2-inches of vertical or axial direction pipe movement. If a valve box is needed, a vertical semirigid sleeve is also needed

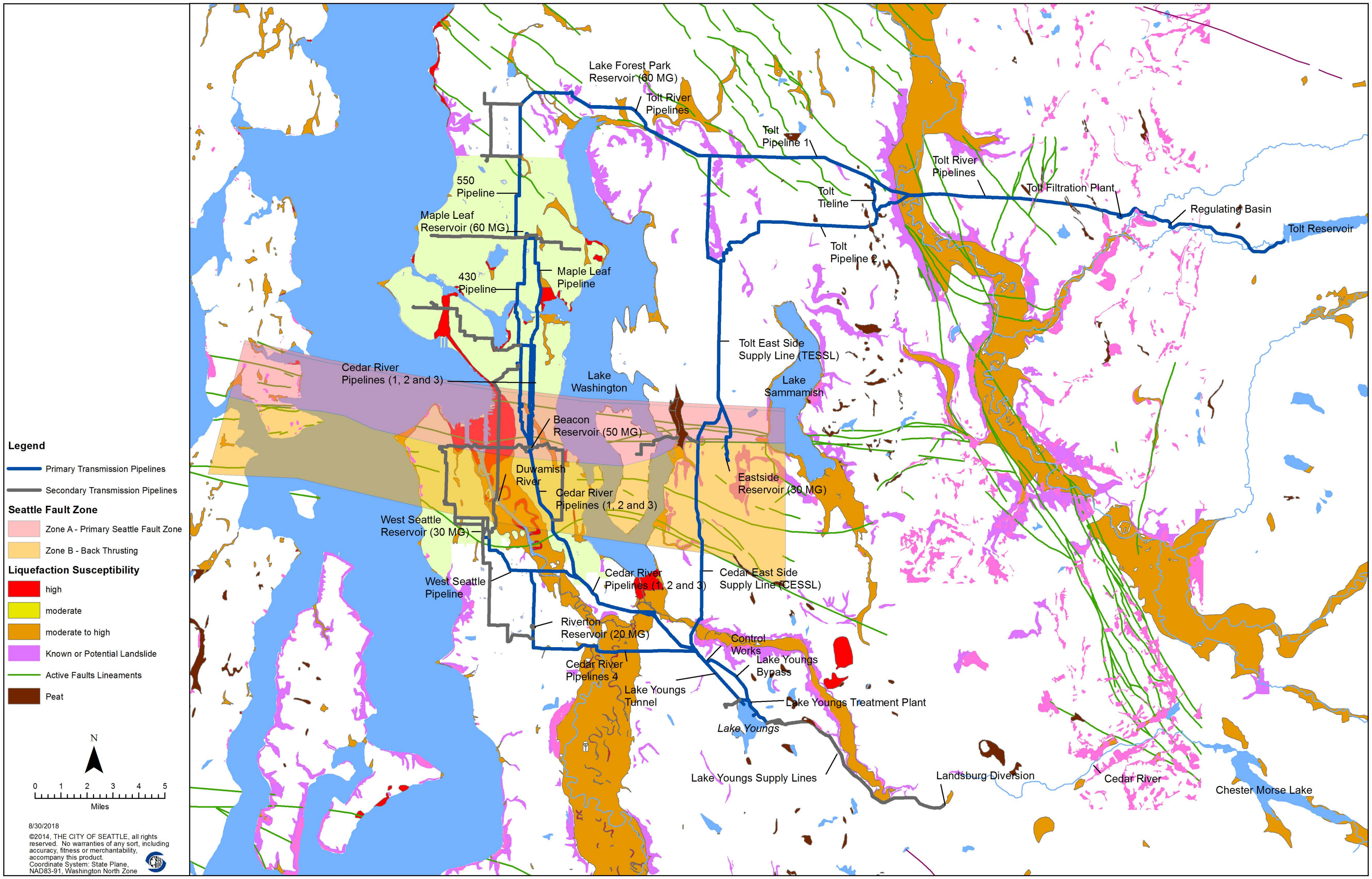

Figure 1. SPU Water Systems Hazards Map

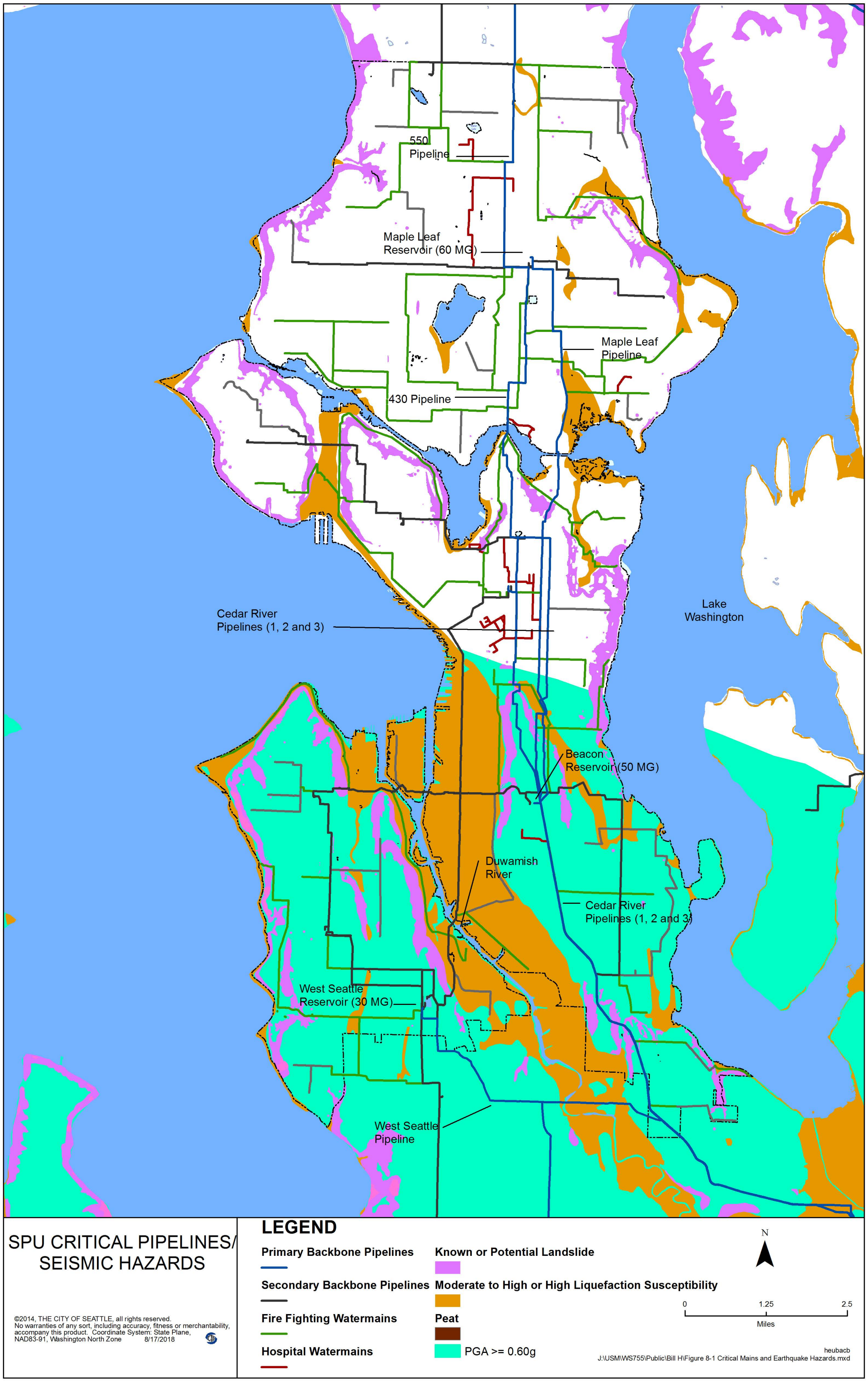

Figure 2. Direct Service Area Seismic Hazards and Critical Pipelines

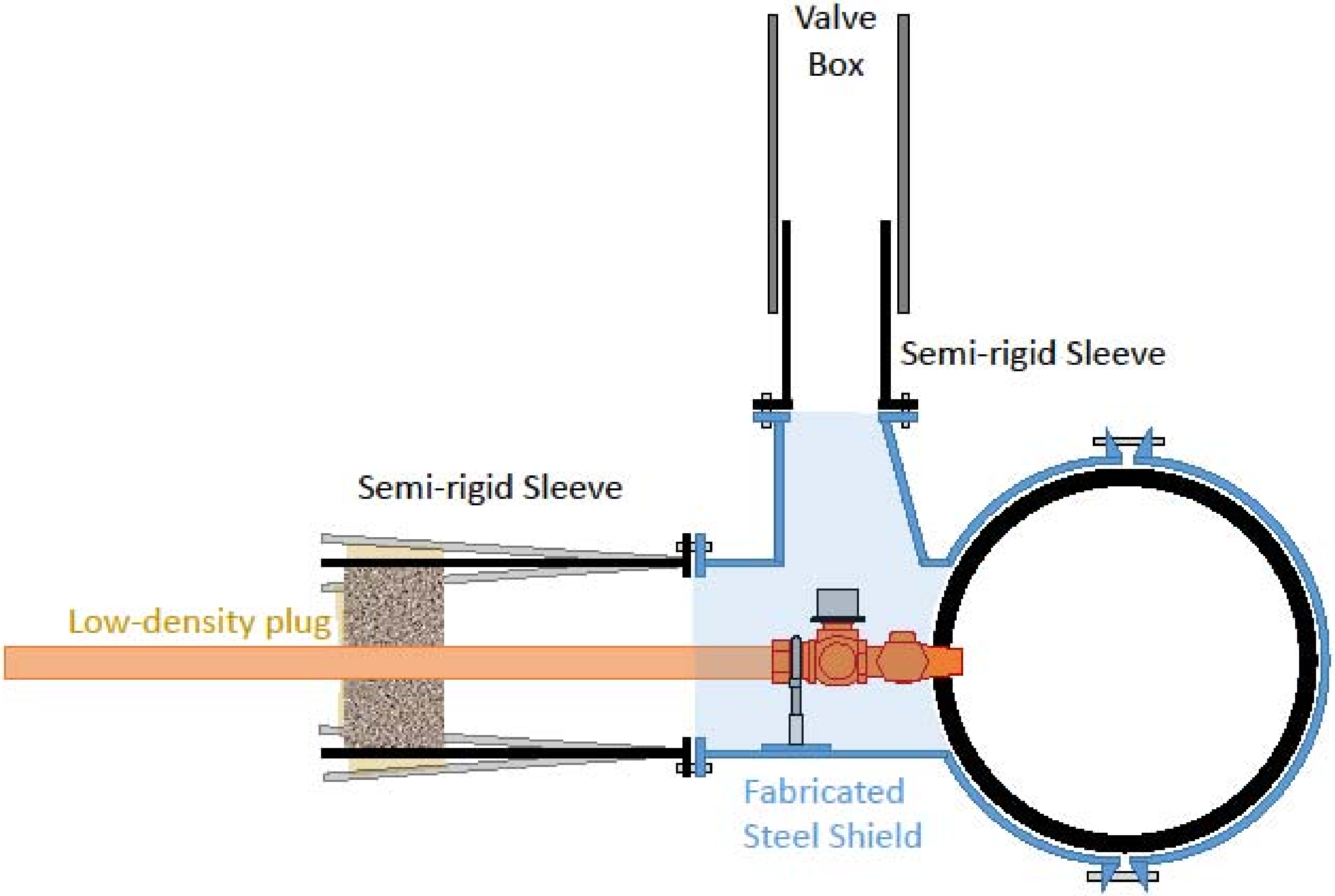

Figure 3. Service Connection

Appendix D References

Lettis Consultants International, 2016, *Final Desktop review and Summary of the Seattle and South Whidbey Island Fault Zones for Seattle Public Utilities*.

Palmer, Stephen P., et. Al., 2004, *Liquefaction Susceptibility and Site Class Maps of Washington State, By County*, Washington Division of Geology and Earth Resources, Open File Report 2004-20.

Pratt, T.L., Troost, K.G., Odum, J.K., and Stephenson, W.J., 2015, "Kinematics of Shallow Backthrusts in the Seattle Fault Zone," *Washington State: Geosphere* 11, No. 6, doi.10.1130/GES01179.1.