Mitchell Park Domes Historical Timeline and Reports
Department of Administrative Services (DAS) Division of Grants & Special Projects
Updated August 12, 2021

Overview

The following is a historical timeline that includes links to the files, reports, and other documents in the County Legislative Information Center (CLIC) related to the Mitchell Park Horticultural Conservatory- most commonly referred to as "The Domes," presented in chronological order beginning with the creation of the Mitchell Park Domes Task Force. This timeline was prepared by the Milwaukee County Division of Grants & Special Projects (DAS) and includes a major contribution by a group of residents, former Domes Task Force members, and elected officials who represent the county and state assembly districts in which the Domes are located, including County Board Supervisor Sylvia Ortiz-Velez and State Representative Marisabel Cabrera-- Milwaukee County thanks them for their efforts related to constructing this timeline. The timeline was subsequently reviewed by a group of internal staff from the Parks Department, including the Director of the Mitchell Park Domes; Architecture, Engineering & Environmental Services (AEES) Division (DAS); and Procurement Division (DAS).

Background of Safety Concerns

In 2013, quarter-sized, sharp-edged chips began to fall from the Domes structure and Milwaukee County worked with Graef, a national engineering, planning, and design firm to do an inspection and make recommendations. In January of 2016, Milwaukee County closed the Domes to the public for over seven months over safety concerns. After reviewing several options, Milwaukee County moved forward with putting in place protective stainless-steel mesh as a short-term solution to safely re-open the Domes to the public, which must be inspected and replaced as needed.

Considerations

The independent and inter-related considerations of this project generally include physical structure (including repairs with manageable maintenance costs, upgrades, accessibility and code compliance, energy efficiency, and functional use); historical significance/historic preservation; plant care/plant health; sustainable revenue structure; public benefits (e.g. education, racial equity, etc.); land use/planning of Mitchell Park; and economic and workforce development.

Item	Name	CLIC Location	Date	Commissioned By	Produced By	Key Findings
1	Substitute Resolution	16-200, Item 3	March 2016	Milwaukee County Board of Supervisors	Milwaukee County Board of Supervisors	- Establishes Domes Task Force - Set County policy to "pursue the repair and preservation of the existing Mitchell Park Conservatory Domes."

2	2016 Update on Costs, Options, Community Engagement	16-636, Item 20	November 2016	Milwaukee County Architecture, Engineering & Environmental Services (AEES)	Graef	- High ($64 million) price tag for replacing rather than repairing glazing -It would cost $2,756,000 to clean, repair, and recoat the entire concrete frame for all 3 Domes -Item Q on page 59 (not labeled) states that ADA code compliance costs would total $250,000 - Horticultural concerns related to the current design of the domes are detailed on page 10 - Row V on page 59 (not labeled) of the report includes an inflationary factor through 2019*
3	Peer Review	16-636, Item 34	March 2017	Domes Task Force Note: National Trust for Historic Preservation paid for this report; WJE Associates is not a Milwaukee County vendor.	Wiss, Janney, Elstner (WJE) Associates	- Review of 2016 Graef report - Emphasized that the glass is repairable and replacement is not necessary - Energy savings of insulating glass stated in Graef report would take 200 years to recover
4	Mitchell Park Horticultural Conservatory Future Path and Feasibility Study ("Phase I Report")	Not available in CLIC	July 2018	Milwaukee County	ConsultEcon, Inc. and HGA	- Mitchell Park Horticultural Conservatory lacks the staff, programming, a relevant governance structure, and versatile spaces needed for success in today's market.

						-Outlines strategies to correct deferred maintenance; expand and enhance the facilities; augment and improve operations and evolve governance. -These improvements will collectively make the Domes more economically sustainable on an ongoing basis. -These approaches will require initial and ongoing investment by the public and private sectors. -The results of implementing a sound strategy for revitalization of the Mitchell Park Domes will bring substantial economic and community benefits to Milwaukee County.
5	THE MITCHELL PARK HORTICULTURAL CONSERVATORY Future Path and Feasibility Study ("Phase II Report")	Not available in CLIC	July 2018	Milwaukee County	Quorum Architects, Inc., HGA, and ConsultEcon	-Details public outreach process, which resulted in more than 2,400 responses on the suggestions presented in the Phase I report (five focus groups with representation from more than 52 organizations/institutions, public meeting, comments via the website, etc.) - The public input suggested a combination of the options

						to initially address deferred maintenance, rehabilitate, and consider future expansion of the facilities and programming to improve the Mitchell Park Domes for another 50 years. -In addition, the public suggested that park and site improvements should be incorporated to proposed Phase 3 planning to complement the enhanced building programming.
6	Phase II Report Appendix	Not available in CLIC	July 2018	Milwaukee County	Quorum Architects, Inc., HGA, and ConsultEcon	Presents Six Options: 1. Do Nothing (will lead to demolition within approx. 5 years) 2. Demolish the Domes, Retain Greenhouses (plant collection is valued at $3.2 million) 3. Address Deferred Maintenance 4. Targeted Investments 5A. EcoDome Destination Attraction 5B. Adventure Dome Destination Attraction 6A. Hybrid Redevelopment EcoDome Destination Attraction (This option is the same as Option 5A, with the exception of the Show Dome being replaced with a new structure.)

						6B: Hybrid Redevelopment Adventure Dome Destination Attraction (This option is the same as Option 5B, with the exception of the Show Dome being replaced with a new structure.)
7	Report: The Domes should evaluate its current admission practices, increase its monitoring of contracts, and establish stronger controls, policies, and procedures in order to position itself for success in the future	19-57, Item 21	March 2019	Milwaukee County Board of Supervisors	Office of the Comptroller, Audit Services Division	-19 recommendations to improve operations and future revenue streams at the Domes
8	Usage of Historic Tax Credits at Mitchell Park Domes	19-55, Item 3	March 2019	Milwaukee County Board of Supervisors	National Trust for Historic Preservation	-Informational report from the National Trust for Historic Preservation regarding historic tax credits and potential applicability to the Milwaukee County Domes
9	Phase III Report (no title), 159 pages	Not available in CLIC	August 2019	Milwaukee County	ArtsMarket, Engberg Anderson Architects, Saikia Design, Preserve, LLC, and Durkin Associates	- Plan proposes a redevelopment of the entire park and doing "historic rehabilitation" on the Domes - Recommends "changing, diverse programming and major touring exhibitions that will draw thousands". -Estimates creation of 300 jobs (combined impact of this direct employment along with the indirect and induced employment is 596 FTE), with a total economic impact of just under

						and $16 million/yr (it is not clear what the calculations are to reach these estimates) - Estimates total investment of $66 million incl. $13.5 million from County and $39 million from Tax Credits and Opportunity Zone Improvements
10	Precast Concrete Frame Testing [Report]	Domes Archive- File 19-102	August 2019	Milwaukee County DAS	Pierce Engineers	- Wall delaminations are minor - Concrete is in reasonably good condition - Concrete frame can last several more decades if a few maintenance interventions are included in future glazing replacement **Note: There are additional safety considerations to the concrete frame. Small pieces of concrete falling from heights up to 85 feet (seven stories) could cause serious injury and is a significant liability (see cost estimate in Item 2).**
11	A New Urban Botanical Park and Conservatory (Final Domes Task Force Plan, 137 pages) **Note: The final plan by the Task Force is highly similar to the Phase III report (Item 9 in the timeline).**	19-677, Item 3	September 2019	Domes Task Force	ArtsMarket, Engberg Anderson Architects, Saikia Design, Preserve, LLC, and Durkin Associates	- Plan proposes a redevelopment of the entire park while preserving the Domes using Historic Tax Credits - Estimates creation of 300 jobs and $16 million/yr in economic impact

						- Estimates total investment of $66 million incl. $13 million from County
12	OCC Independent Legal Analysis of Recommendations of the Domes Task Force	19-736	September 2019	Domes Task Force, Milwaukee County Board of Supervisors	Office of the Corporation Counsel	-Preliminary thoughts in response to eight specific questions asked by the Domes Task Force (not a final legal analysis), including: 1. Whether creation of a non-profit corporation to operate the Domes is possible; 2. Whether Milwaukee County is eligible for historic or new market tax credits; 3. Whether Milwaukee County can mandate wages for labor described in the plan; 4. Whether the proposed tax credits are feasible; 5. An opinion on the required legal contracts to move the project forward, and how they will coordinate with or be managed; and 6. Assessment of potential impacts to the existing Zilli arrangement. (Two additional questions were addressed within the context of other responses.) -OCC states that probing whether the projections, funding sources, and funding estimates contained in the plan are realistic is an

						essential next step. -Additionally, OCC states that the plan does not identify "a fiscally-sustainable, likely to succeed, operationalizable, detailed business plan to market to potential private sector partners and granting entities".
13	Glazing System Investigation Part I- Assessment	Domes Archive- File 19-102	December 2019	Milwaukee County DAS	ZS Architectural Engineering	- Presents 3 options for (ONLY) glazing repair for all 3 Domes from $18,845,000- $19,500,000 total - All options provide life span far in excess of 20-year system warranty
14	Status of Implementing Dept. of Audit Report Recommendations	21-233	March 2021	Milwaukee County Board of Supervisors	Office of the Comptroller, Audit Services Division	-Updates regarding the status of the 19 recommendations to improve operations and future revenue streams at the Domes (see item 4)
15	Information about the partnership between the Milwaukee Public Museum and Milwaukee County and if a similar arrangement is possible between the Mitchell Park Horticultural Conservatory and Milwaukee County	Appendix A	March 2021	Supervisor Ortiz-Velez	State of Wisconsin Legislative Reference Bureau (LRB)	-The statutes do not appear to prevent Milwaukee County from managing the conservatory in the same way as it does the Milwaukee Public Museum per the County's home rule authority under Wis. Stat. § 59.03 (1)
16	[To come] Glazing System Investigation Part II- Study of Glazing Mock-up and Water Testing	---	Anticipated in December 2021	Milwaukee County	ZS Architectural Engineering + SuperSky	---

17	Mitchell Park Horticultural Conservatory Facility Improvements Request (Horticulturalist Team) August 5, 2021.docx	Appendix B	August 2021	GSP	The Domes Horticultural Experts	-Horticulturalists recommend a number of structural and operational improvements to benefit the plants and increase efficiency and safety
18	[To come] Updated cost estimates to the 2016 Graef report	---	Anticipated in November 2021	GSP	Graef	---

*AE&ES has requested a proposal from Graef to update the cost estimates in the 2016 technical report to go through 2024.

Reports:

File 16-200 Additional funding request for protective netting and long-term planning costs related to existing capital project WP49001 - Mitchell Park Domes (March 2016)

- Substitute Resolution (Item 3) by former Chairman Lipscomb, and Supervisor Broderick
  - Creates the Domes Task Force
  - Establishes the Domes Task Force and set County policy to "pursue the repair and preservation of the existing Mitchell Park Conservatory Domes."
  - Includes a resolution establishing $500,000 for netting repair

File 16-636 Informational reports relating to the Milwaukee County Task Force on the Mitchell Park Conservatory Domes, authorized by adopted File Number 16-200.

- Domes Task Force meets for the first time on August 12, 2016
- Item 13: MITCHELL PARK DOMES PLANNING FUNDS UPDATE (November 2016)
  - The existing contract is executed with Graef, Inc. and is focused on initial planning and outreach efforts. The contract does not include facility programming or design, which would come in future work associated with the long-term planning effort.

Item 20: 2016 UPDATE ON COSTS, OPTIONS, COMMUNITY ENGAGEMENT (December 2016)

- Summary:
  - Prepared by Graef, Commissioned by Milwaukee County
  - Established the high price tag on the Domes because it required replacement rather than re-glazing
  - Report offers an "Option R: Replace All Glass – Install New Façade – Rebuild Concrete Frame per Original Construction" at a cost estimate of $64 million, to last for 50 years. (This option is not consistent with Resolution 16-200)

Item 23: COST OPTIONS COMPARISONS 2016 (Revised: January 2017)

- Slide 59: Survey shows 64% favor repair

File 16-636 Item 34: "Mitchell Park Domes Peer Review Final (March 2017) and Item 35: "Peer Review Electronic Presentation (March 2017)

The National Trust for Historic Preservation sponsored Wiss, Janney, Elstner (WJE) peer review of Graef replace and repair options reports.

- Summary
    - WJE has extensive national experience in historic preservation
    - Provided an analysis based on Graef reports
    - WJE provides a summary of options 1-5 + R and corresponding expenses on Page 26:
        - Options 2 through 4 use coated insulating glass at a cost of approximately three to four times the repair cost of Option 1
        - Difference between Options 1 and 2 is the replacement of all wired glass with coated insulating glass ($24 million additional)
            - Insulating glass is not recommended, as it is not beneficial to plant life (based on horticulturists)
            - The energy efficiency savings of insulating glass would take nearly 200 years to recover
    - Lists all the Graef reports available at that time (p. 18 of PDF, p. 15 of report)
    - Item 43: The County and Graef review the WJE Peer Review
    - Item 44: WJE response to Graef review

Item 82: 16-363 Future Path and Feasibility Presentation Revised (December 2017)

Option	Estimated Cost	Estimated Life	Maintenance	Wire Mesh
1	$14 million	5-10 years	Very High	Remains
2	$38 million	15-20 years	High	Remains
3	$47 million	25-30 years	High	Remains
4	$54 million	25-30 years	High	Removed
5	$50 million	50 years	Normal	Removed
R	$64 million	50 years	Normal	Removed

- Among many conclusions the report establishes that there are several opportunities for targeted investments, with a modest investment returning a modest to significant impact. (Page 9)
- Establishes that seeking partnerships to broaden the audience of the Conservatory that bring expertise, programming capabilities and funding related to topics that have a natural synergy with the horticultural mission of the Domes vision is a modest investment with a significant impact. (Page 13 to 15)
- Established a model which would provide pivotal for the Arts Market report later on.

- Considers an additional 5 other Domes options ranging from $14M (to last 5 to 10 years with high maintenance) to $54M (to last 25 to 30 years with high maintenance.)
- See more recent reports/estimates by WJE, ZS Engineering, and Pierce Engineers.

File 18-164 Phases I & II (Feasibility Study Research and Analysis & Community Outreach, 2016-2018)
Item 39: Domes Future Path and Feasibility Study Corrected **(August 2018)**

- Quorum Architects surveyed the public and found that over 70% of the 2,300+ participants are interested in having Milwaukee County lead a process toward restoring, redeveloping, and improving the Domes into a destination attraction for Milwaukee County for generations to come.
- Concludes the lack of supportive spaces including classrooms, offices, appropriately sized and outfitted retail and food service space limits the Domes effectiveness as public attractions.
- Market research and comparable facilities analyses indicate that there are several approaches to achieving a robust future for the Domes.
- The Task Force agreed that at the very least repair of the Domes must be accompanied with a mix of physical improvements, operational improvements, and governance changes.
- The Task Force accepted the consultants' conclusion that rebuilding or replication of the Domes would not merit the cost due to their finding that a new conservatory alone would not increase the Domes revenue enough.

File 19-55 Memo on the Use of Historic Tax Credits (February 2019)
A memo and a presentation regarding the use of Historic Tax Credits for the restoration of the Domes, drafted by internationally renowned firm Nixon Peabody, for the National Trust for Historic Preservation.

- 19-55 - Microsoft PowerPoint – Domes Historic Tax Credits NTHP_021919 (Item 2)
- 19-55 Microsoft Word - NTHP cover memo to NixonPeabody HTC memo FINAL (Item 1)
  - It may be possible to utilize federal HTCs to help fund rehabilitation of the Domes.
  - There are many examples of government-owned properties around the country that have successfully utilized Historic Tax Credits to support large rehabilitation projects.
  - Federal HTCs could provide several million dollars of project equity, depending upon the total rehabilitation cost.
  - Federal HTCs would likely not be available if one or more Domes are demolished, partially demolished, or rebuilt.
  - Public-private partnerships would be necessary in order for the County to take advantage of the Federal HTCs.

File 19-102 2019 Informational file for the Domes Task Force
There are 83 informational reports attached to the file pertinent to 2019 Domes Task Force activities. Of special importance are reports and presentations from Gallagher (Milwaukee Public Museum), ArtsMarket, and public comments. However, many of the reports are duplicates, some are meeting minutes, and many are Domes Task Force meetings audio recordings.

File 19-677 Phase III – Task Force Report & Recommendations (September 2019)

- 19-677 (Item 3), A2 - Future Path and Feasibility Study – Phase 3 Report (137 Pages)
  - The plan is a preservation solution that creates a New Urban Botanical Park and Conservatory
  - Concludes "The Domes are historically important for their architecture and engineering. There is no other structure like them anywhere in the world. They will be rehabilitated for the next 50 years, with important added elements to enhance the visitor experience."
  - Plan is an economic engine for the neighborhood, sustaining 300 quality jobs and a hub for workforce development.
  - Will stimulate an annual economic impact of just under $16 million a year in combined on-site and off-site jobs and spending.
  - Within 10 years the economic impact of the plan totals $160 million.
  - Report includes a draft application for listing on the National Register of Historic Places

- 19-677 (Item 2 dated September 5, 2018) Memo from Deputy Corporation Counsel Paul Kuglitch
  - Concludes that any future plan options considering demolition of any or all of the Domes was inconsistent with the County Board Resolution establishing the Domes Task Force (16-200)
- 19-677 (Item 5) ArtsMarket Appendix
  - Addresses questions from the Milwaukee County Parks Department.

Technical Reports (Concrete, Glazing, WJE Peer Review)

The last meeting of the Domes Task Force was in August 2019, before the Concrete and Glazing reports were finalized. Both of these reports were commissioned by Milwaukee County. The reports do not appear to be available on CLIC, but MPA is able to provide (see Appendix C).

- Concrete Reports (August 2019)
  - Wall delaminations are minor
  - Concrete members are sound with good design strength and not showing signs of progressive deterioration from any of the common distress mechanisms.
  - Concrete frame can last several more decades if a few maintenance interventions are included in future glazing replacement

- Glazing Assessment- Two Parts (December 2019)
  - Presents 3 options for glazing repair for all 3 domes from $18,845,000-$19,500,000 total
  - All options provide life span far in excess of 20-year system warranty
  - The second and third options are the options that would most preserve the exterior appearance of the Domes.
  - Implementation of any of these repair concepts will provide a new extended life for the Domes
  - This report does not include additional structural considerations or costs related to falling pieces of concrete

- Glazing System Investigation Part II- Study of Glazing Mock-up and Water Testing to be completed by December of 2021

The work of the Domes Task Force concluded in the third quarter of 2019, forwarding a plan drafted by ArtsMarket to the County Board. The County Board subsequently approved $107,998 (1A008) in the 2020 Budget to pursue further planning for the Domes following the recommendations made by the Task Force. Additionally the County Board transferred $50,000 (19-802) for the purpose of completing due diligence by the Office of the Comptroller related to the plan recommended by the Task Force. Those funds were lost at the end of the year (2020). However, funds were once again approved in the 2021 budget. The County Board approved $75,000 in the 2021 budget (1A020) for the exploration of potential funding sources for the repair and restoration of the Mitchell Park Horticultural Conservatory (Domes).

APPENDIX A

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MEMORANDUM

TO: Representative Sylvia Ortiz-Velez

FROM: Staci Duros, legislative analyst

DATE: March 16, 2021

SUBJECT: Milwaukee Public Museum

You requested information about the partnership between the Milwaukee Public Museum and Milwaukee County. Specifically, you wanted to know how the partnership works and if a similar arrangement is possible between the Mitchell Park Horticultural Conservatory and Milwaukee County.

Milwaukee Public Museum

In Wisconsin, any county may acquire, establish, expand, own, operate, and maintain a public museum in the county and appropriate money for such purposes.[1] The term "public museum" is not defined. Currently, Milwaukee County retains ownership of the Milwaukee Public Museum's collections, museum facilities, and land, while the museum's operational management and collections care is performed by the Milwaukee Public Museum, Inc. (MPMI), a not-for-profit corporation and a 501 (c) (3) organization[2] formed in 1991 specifically for the purpose of managing the museum.[3] Under the most recent Leasing and Management Agreement, signed in 2013, Milwaukee County "owns the current museum building at 800 West Wells Street and all of the artifacts, exhibits, and other items of historical or scientific value or significance owned or held by the County and used or intended to be used for exhibition, display, education or

[1] Wis. Stat. § 59.56 (2).
[2] Under 26 U.S. C. § 501 (c) (3), certain entities "organized and operated exclusively for religious, charitable, scientific, testing for public safety, literary, or educational purposes" are exempt from federal income tax. To qualify for exemption as a 501 (c) (3) organization, organizations must file an application with, and be recognized by, the Internal Revenue Service. For more information on 501 (c) (3) status, see Internal Revenue Service, *Applying for 501(c)(3) Tax-Exempt Status*, Publication 4220 (March 2018).
[3] Milwaukee Public Museum, *Strategic Plan 2018-2022* (November 20, 2019), 3. The operating history of MPMI as a corporation can be found in Scott Walker, *Milwaukee County: 2010 Adopted Budget*, 381.

research" and leases "the current building, the personal property, and the artifacts" to MPMI, whose primary responsibility is to "manag[e] and operat[e]" the museum.[4] The initial term of this agreement is through December 31, 2022, and the agreement can be automatically extended for four successive periods of five years each through December 31, 2042.[5] The agreement also includes financial support from Milwaukee County in the form of an annual operating contribution. For the last four years, the county's annual contribution was $3,500,000.[6]

In 1993, the Wisconsin Supreme Court decided a case that is relevant to this discussion and sheds light on the second question that this memorandum discusses—whether a similar arrangement is possible between the Mitchell Park Horticultural Conservatory and Milwaukee County. In *Hart v. Ament*, a group of Milwaukee County taxpayers challenged Milwaukee County's authority to enter into a lease and management agreement with MPMI that transferred operational management from the county itself to MPMI.[7] The court upheld the county's authority under three specific statutory provisions: a county's home rule authority under Wis. Stat. § 59.025 (1991), a county's authority to convey county property under § 59.07 (1) (1991), and a county's authority to establish and maintain a public museum under § 59.07 (33) (1991).[8] These provisions have since been renumbered—to Wis. Stat. § 59.03 (1), Wis. Stat. § 59.52 (6), and Wis. Stat. § 59.56 (2), respectively—but their substance remains largely unchanged.

A county's home rule authority under Wis. Stat. § 59.03 (1) allows every county to "exercise any organizational or administrative power, subject only to the constitution and to any enactment of the legislature." Additionally, a county's home rule authority must be "liberally construed in favor of the rights, powers and privileges of counties to exercise any organizational or administrative power" to "give counties the largest measure of self-government."[9] A county also has the authority to acquire, control, and transfer property under Wis. Stat. § 59.52 (6). Paragraph (a) of this statute allows a county board to acquire property, par. (b) allows it to "[m]ake all orders concerning county property," and par. (c) allows it to "lease, sell or convey or contract to sell or convey any county property" except for property that is "donated and required to be held for a special purpose." Lastly, Wis. Stat. § 59.56 (2) permits a county to operate and maintain a public museum. The court concluded that Milwaukee County had the statutory authority to enter into a lease and management agreement with MPMI that transferred operational management from the county itself to MPMI.[10]

[4] Milwaukee County, *2021 Adopted Operating Budget* (October 2020), 404.
[5] *Id*.
[6] Milwaukee County, *2021 Adopted Operating Budget* (October 2020), 406. The county's annual operating contribution amount is based on MPM meeting operating and financial goals outlined in the agreement; if these goals are not met, the county may reduce its annual operating contribution for the subsequent year (*Id*., Footnote 2).
[7] Hart v. Ament, 176 Wis. 2d 694 (1993).
[8] *Id*., at 701.
[9] Wis. Stat. § 59.04.
[10] Hart v. Ament, 176 Wis. 2d 694, 704 (1993).

Mitchell Park Horticultural Conservatory

Currently, the Mitchell Park Horticultural Conservatory is owned and operated by the Milwaukee County Park System, a department of Milwaukee County. The statutes do not appear to prevent Milwaukee County from managing the conservatory in the same way as it does the Milwaukee Public Museum.

I hope that you find this information useful. Please let me know if I can provide any additional assistance.

APPENDIX B

MEMO

To: Nichole Todd, Grants & Special Projects Division
CC: Jim Tarantino, Director of Recreation & Business Services**,** Milwaukee County Parks Dept.
From: Doris Maki, Horticultural Services Director, Milwaukee County Parks Dept.
Date: August 5, 2021
Re: Domes Facility Improvements for Domes Project Planning

The Mitchell Park Horticultural Conservatory, also known as The Domes, has a horticultural team comprised of a supervisor and six horticulturists who oversee and maintain the permanent plant collections, rotating floral exhibits, and greenhouse growing operations. There is one horticulturist assigned to each dome (Show Dome, Desert, and Tropical), two horticulturists for the greenhouses, and one rotating/outdoor gardens horticulturist. Below are recommendations from the horticulture staff for needed facility services and improvements with the focus on plant care and horticultural operations, divided into operational and structural:

<u>Operational</u>

1) Create one new full-time park maintenance worker with the focus on conservatory and greenhouse maintenance. This new position would have access to the knowledge and skills required to ensure the longevity of our systems and facility inputs from existing staff.
2) Current rotating floral exhibits (5) in the Show Dome are extremely labor intensive. We propose a more integrated dynamic floral display. This would open the opportunity to invest in permanent, high quality, aesthetically pleasing features such as raised beds, green walls, water features, sculptures, and the ability to hang props and art above beds. Relieving the labor intensiveness of show change would also give horticulturists the opportunity to invest more time in intricate design for a more polished professional look.

<u>Structural</u>

1) Repair and replace the domes' glass structures in order to eliminate leaks. Leaks present a slipping hazard to the public as well as employees in all three Domes. They cause damage to floral exhibits in the Show Dome, plant collections in the Desert Dome, and events and display items throughout.
2) Update fertilization system with easier access. Our current system is inadequate and most assuredly has an inaccessible sedimentary buildup within it. All plumbing inside each Dome must be replaced and/or updated to keep up with proper maintenance of the plants. A modern injector fertilization system like the one installed in the greenhouse complex would be suitable for each Dome.

3) Update Climate Control System. Our current system is for commercial buildings and not ideal for a horticultural conservatory. It overheats catwalks in the Tropical Dome and temperatures fluctuate unreliably for all three Domes.
4) Widen paths for better access. Current walkways/paths inside the Desert and Tropical Dome are narrow and sloped making it difficult to maneuver equipment needed for periodic pruning and replacements. Permanent paths with a raised edge to replace current perimeter walkway and woodchipped temporary paths. All paths to be ADA compliant.
5) Widen doorways/frames. The doorways into the Domes are small which increases the difficulty in access for maneuvering boom lifts and forklifts required for plant maintenance.
6) Add access doorway for compost waste. It is not efficient or professional for staff to haul their plant debris from the Tropical Dome, Arid Dome, or greenhouses through the public lobby to get to the compost dumpster behind the Show Dome. A better design would have a way for staff to dispose of the debris right out the back door of each dome.
7) The Transition Greenhouse needs updating, including replacing and resealing the glass, and adding shade cloth for the orchid room and portion of the transition house for the Tropical Dome.
8) Address the large perimeter stone walls, which are causing lighting issues in the Desert and especially in the Tropical Dome. The lack of sunlight close to these walls causes challenging conditions and compromises to plant growth.
9) The current misting irrigation system in the Tropical Dome is old and needs upgrading. This would be greatly beneficial to the large specimen trees in the collection.
10) Irrigation access for planting bed should be installed by the roadside digital sign. Curb access for front circle bed and a permanent edging/ walk is needed for the circle bed.
11) Storage space is greatly needed for the domes and greenhouses. Supplies in close proximity to the domes structures themselves will assist in lessening the staff time and effort needed to transport materials back and forth from the greenhouses to the conservatory. Storage is also needed to house all the rental furniture and/or equipment currently stored in the greenhouse complex, which is used to accommodate rentals due to our long-term agreement with ZHG. Friend of the Domes (FOD) can also benefit from additional storage as their supplies and special event props and materials are currently stored in the Domes basement and more space is needed as they continue to grow as an organization and currently manage the Gift Shop and Education Center.

APPENDIX C

MITCHELL PARK HORTICULTURAL CONSERVATORY
MILWAUKEE, WISCONSIN
PRECAST CONCRETE FRAME TESTING

PE # 19257

August 26, 2019

By

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&

IDENTIFIED SUB-CONSULTANTS

EXECUTIVE SUMMARY

Pierce Engineers and a team of sub-consultants performed materials testing on the precast concrete frame and a foundation condition assessment of the Show Dome at the Mitchell Park Horticultural Conservatory. The assessment work was performed May 16 to June 3 of 2019. The assessment of other domes is not part of the scope of this report.

Methodology: Sampling locations were selected by team to represent the varied conditions of the precast concrete frame. See Appendix A for photographs of locations.

- Geotechnical Analysis: The bearing capacity of the pavers was performed prior to the introduction of the telescoping man lifts on to the paver paths, see appendix B for lift information.
- Structure Survey: Two surveys (pre and post of materials sampling operations) performed by Burse Surveying & Engineering, Inc., using a total station, no movement was detected, see appendix D
- Foundation Overview & Condition Assessment: The foundation of the show dome is a pair of concentric rings, see plan S101. Pierce Engineers' condition assessment of the concrete foundation used visual assessment, sounding, and sonic / ultrasonic testing. Delamination soundings are denoted in the foundation plan survey & photos attached in appendix D. Concrete wall delamination are minor, most due to low concrete cover. Repair of all concrete wall and slab delaminations can be accomplished by conventional repair methods.
- Precast Concrete Frame Testing: Vector Corrosion Services (VCS) performed a corrosion and material evaluation of the concrete frame while NDT Corporation conducted a non-destructive evaluation of the concrete elements. The focus of the evaluation was to identify the extent of concrete deterioration that cannot be observed through tactile inspection alone. This includes corrosion activity, concrete degradation, concrete strength, condition of grout pockets, and weld plates. Testing included the following; Ground penetrating radar (GPR), Electrical continuity, Corrosion Potential Survey, Sonic/Ultrasonic Measurements, Concrete Material Sampling testing for chloride and carbonation, along with exposing two joint locations by grout removal. VCS' report states the following with regard to concrete frame corrosion: "Overall, the findings indicate that the SHOW DOME concrete frame is in reasonably good condition. Concrete members are sound, it has good design strength, and is not showing signs of progressive deterioration from any of the common distress mechanisms (corrosion, reactive aggregate, freeze-thaw, chemical attack). The problems identified stem from initial design and construction. So, if the representative areas tested are actually representative of the overall conditions, the SHOW DOME concrete frame can last several more decades if a few maintenance interventions are included in any future glazing replacement effort. There really is no deterioration mechanism other than the very mild corrosion found that should shorten the life of the SHOW DOME." In Appendix F, VCS presents full description of testing including data collected, an interpretation of results including a summary of findings, recommended concrete frame maintenance and application of findings to other domes

INTRODUCTION

Pierce Engineers and a team of sub-consultants performed materials testing on the precast concrete frame and a foundation condition assessment of the Show Dome at the Mitchell Park Horticultural Conservatory, 524 S. Layton Blvd., Milwaukee, Wi 53215. The assessment work was performed May 16 to June 3 of 2019.

The consultant team consisted of the following entities:

• Pierce Engineers (PE)	Restoration Consultant
• Vector Corrosion Services (VCS)	Corrosion & Concrete Material Specialists
• NDT Corporation	Non-destructive & Geophysical Testing Services
• Soils & Engineering Services Inc. (SES)	Geotechnical Engineers
• Burse Surveying & Engineering, Inc.	Surveying
• Arteaga Construction, Inc	General Contractor

METHODOLOGY

Sampling locations were selected by team to represent the varied conditions of the precast concrete frame. See Appendix A for photographs of locations.

SUB-SOIL INVESTIGATION

Geotechnical analysis of the bearing capacity of the pavers was performed prior to the introduction of the telescoping man lifts on to the paver paths, see appendix B for lift information. Arteaga Construction performed select removal of pavers in both locations (1 & 2) where lifts will be operated. Soils & Engineering Services Inc. (SES), Geotechnical Engineers performed field and laboratory analysis of soils under both lift locations, see appendix C.

STRUCTURE SURVEY

Two surveys were performed, pre and post of materials sampling operations to verify the exact location of the perimeter and if any movement occurred during testing. Burse Surveying & Engineering, Inc. performed a total station survey of both locations using 7 targets each frame location, see addendum D. No movement was detected, see appendix D.

FOUNDATION OVERVIEW

The foundation of the show dome is a pair of concentric rings, see plan S101. These foundation rings are formed in either single segments (interior) or double segments (exterior) in each sector as noted on the plan. The exterior primary foundation wall is located directly underneath the precast dome framing base providing its foundation. The interior secondary foundation wall is offset to the interior creating a 5'-0" wide mechanical areaway with a top of areaway slab-on-grade approximately 8 feet below the interior grade (planting area) within the dome.

The only visible faces of the pair of foundation walls is from within this areaway. The interior side (towards the center of the dome) of interior wall ring is retaining the planting area soil. The exterior face of the exterior wall is likewise only visible from within the areaway, although the wall extends above exterior grade and is cladded with a precast exposed aggregate panel.

The exterior wall has a cast-in-place gutter which extends ¾ of the circumference of the foundation, omitted at the loading dock and interior lobby spaces. This gutter was originally formed with water-stops and observations showed no issues with leaking into the show dome to the interior areaway below.

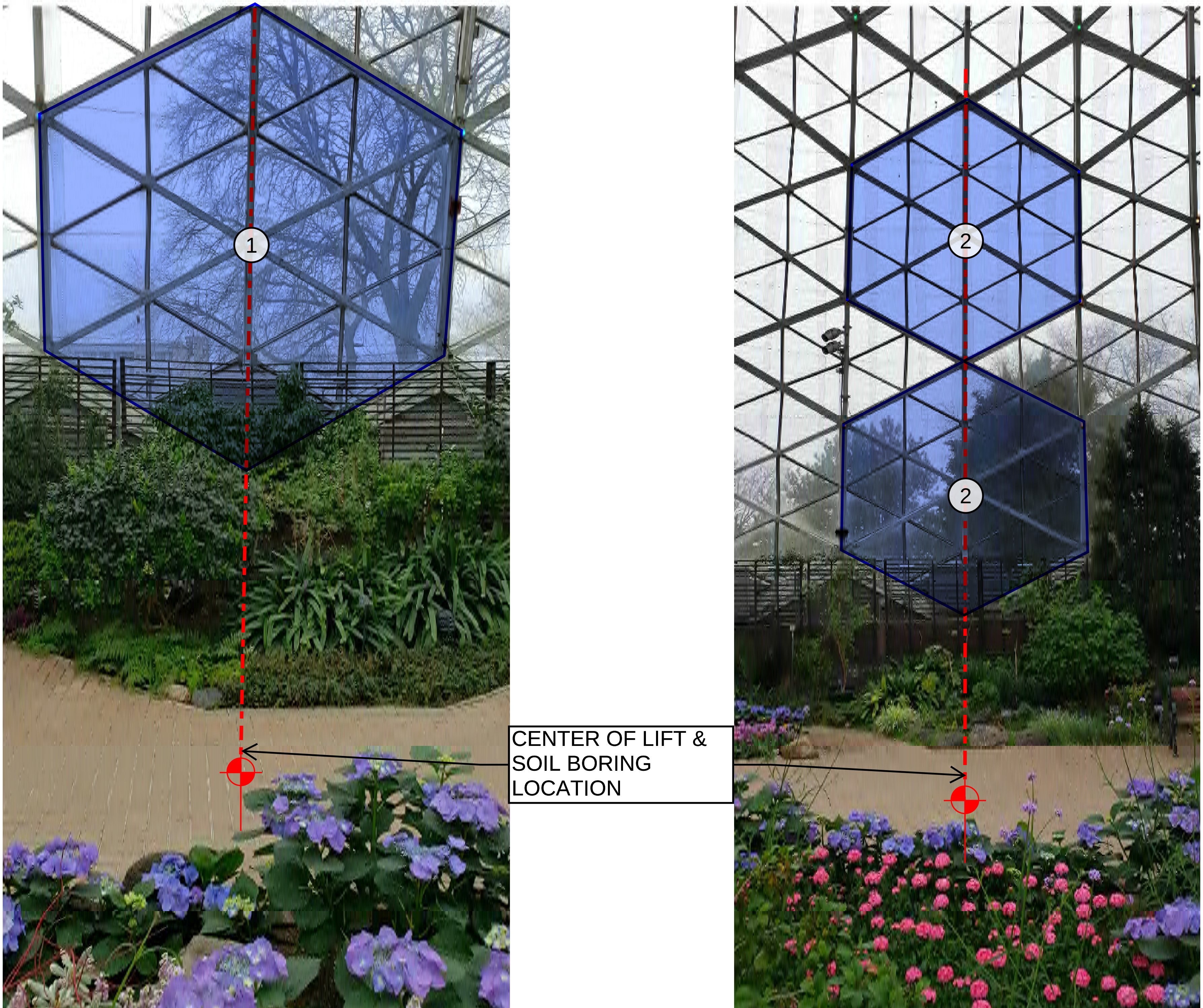
FOUNDATION CONDITION ASSESSMENT

Condition assessment of the concrete foundation was performed by Pierce Engineers via visual assessment, sounding, and sonic / ultrasonic testing of both faces of foundation from the below grade areaway. Sonic / ultrasonic measurements are discussed in VCS, Table 5.

Delamination soundings are denoted in the foundation plan survey & photos attached in appendix D. Concrete wall delamination noted on plans were minor, most due to low concrete cover where reinforcing is near surface, with the largest area of 5sf. Repair of all concrete wall and slab delaminations can be accomplished by conventional repair methods. Conventional repair of delaminations by removing delaminated concrete to sound substrate exposing corroded reinforcing should be performed, Perform surface preparation of concrete and steel reinforcing within patches via gritblasting to remove loose materials and bond inhibiting materials. Place concrete repair mortar and provide breathable concrete coating for protection of low cover reinforcing.

APPENDIX A
MATERIALS TESTING LOCATIONS

Location 1 & 2



Location 1

Location 2

Pavers

APPENDIX B
BOOM LIFT SPECIFICATIONS

E SERIES

ELECTRIC BOOM LIFTS

reachingout™

Performance

Platform Height		
E300AJ	30 ft 2 in.	9.19 m
E300AJP	29 ft 5 in.	8.96 m
E400AN/E400AJP/M400AJP/ E400AJPN/M400AJPN	40 ft	12.19 m
E450A/E450AJ/M450AJ	45 ft	13.72 m
Horizontal Outreach		
E300AJ	20 ft 3 in.	6.17 m
E300AJP	20 ft 1 in.	6.12 m
E400AN	21 ft 2 in.	6.45 m
E400AJP/M400AJP/ E400AJPN/M400AJPN	22 ft 5 in.	6.83 m
E450A	23 ft 1 in.	7.04 m
E450AJ/M450AJ	23 ft 9 in.	7.24 m
Up and Over Height		
E300AJ/E300AJP	13 ft 2 in.	4.01 m
E400AN/E400AJP/M400AJP/ E400AJPN/M400AJPN	21 ft 6 in.	6.55 m
E450A	24 ft 7 in.	7.49 m
E450AJ/M450AJ	25 ft 3 in.	7.7 m
Swing	360° Non-continuous	
Platform Capacity	500 lb	227 kg
Platform Rotator	180° Hydraulic	
Weight		
E300AJ	15,060 lb	6,831 kg
E300AJP	15,400 lb	6,985 kg
E400AN	13,100 lb	5,942 kg
E400AJP/M400AJP	13,700 lb*	6,214 kg
E400AJPN/M400AJPN	14,900 lb*	6,759 kg
E450A	12,600 lb	5,715 kg
E450AJ/M450AJ	14,400 lb*	6,532 kg
Ground Bearing Pressure		
E300AJ/E300AJP	170 psi	11.95 kg/cm^2
E400AN	95 psi	6.7 kg/cm^2
E400AJP/M400AJP	80 psi	5.6 kg/cm^2
E400AJPN/M400AJPN	185 psi	13 kg/cm^2
E450A	95 psi	6.7 kg/cm^2
E450AJ/M450AJ	110 psi	7.6 kg/cm^2
Max Drive Speed		
E300AJ/E300AJP	4.5 mph	7.2 km/h
E400AN/E400AJP/M400AJP/ E400AJPN/M400AJPN	4.5 mph	7.2 km/h
E450A/E450AJ/M450AJP	4.5 mph	7.2 km/h
Gradeability		
E300AJ/E300AJP	25%	
E400AN/E400AJP/M400AJP/ E400AJPN/M400AJPN	30%	
E450A/E450AJ/M450AJP	30%	
Turning Radius (inside)		
E300AJ/E300AJP	5 ft	1.52 m
E400AN	2 ft 10 in.	.86 m
E400AJP/M400AJP	2 ft	.61 m
E400AJPN/M400AJPN	2 ft 10 in.	.86 m
E450A/E450AJ/M450AJP	2 ft	.61 m
Turning Radius (outside)		
E300AJ/E300AJP	10 ft 2 in.	3.1 m
E400AN/E400AJP/M400AJP/ E400AJPN/M400AJPN	10 ft 4 in.	3.15 m
E450A/E450AJ/M450AJP	10 ft 4 in.	3.15 m

Lift used by domes staff

Rental for concrete sampleing work

*For M models, add 300 lb (136 kg).

Standard Specifications

Power Source

Electrical System	48V DC	
Batteries	8 x 6V, 370 amp-hr (305 amp-hr on E300)	
Drive Motors	Dual Electric Traction—Brushless AC	
Generator Set (M Models)		
Diesel Engine Kubota 45 amp	6.7 hp	4.99 kW
Fuel Tank Capacity	4 gal.	15.2 L

Hydraulic System

• E300AJ/E300AJP	2.1 gal.	7.95 L
• E400AN/E400AJP/M400AJP/ E400AJPN/M400AJPN	4 gal.	15.14 L
• E450A/E450AJ/M450AJP	4 gal.	15.14 L
• Motor/Pump	Permanent Magnet Motor/Gear Pump	

Tires

• E300AJ/E300AJP	25 x 7 x 12 Non-marking
• E400AN/E400AJPN/M400AJPN (front)	22 x 6 x 17.5 Non-marking
• E400AN/E400AJPN/M400AJPN (rear)	25 x 7 x 12 Non-marking
• E400AJP/M400AJP	240/55-17.5 Pneumatic
• E450A/E450AJ/M450AJ	240/55-17.5 Pneumatic

Standard Features

- Automatic Traction Control (ATC)
- Side Entry Platform
- 180 Degree Hydraulic Platform Rotator
- 110V-AC Receptacle on Platform
- Tilt Light and Alarm
- Hourmeter
- Battery Condition Indicator
- Lifting/Tie Down Lugs
- Horn
- All Motion Alarm
- Eight 6V 370 amp-hr Deep Cycle Batteries
- Brushless AC Motors

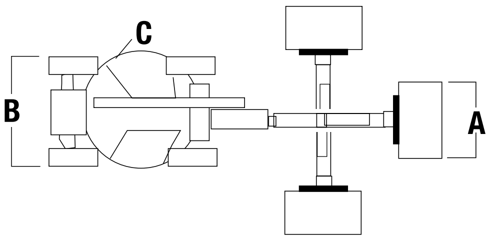
Accessories & Options

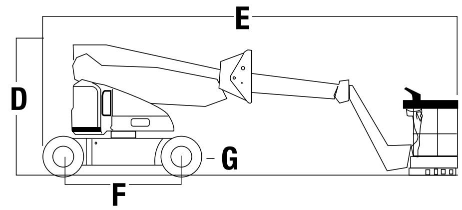
- Inward Self-closing Swing Gate
- Platform Worklights
- Mesh to Top Rail—Bolt-on Aluminum
- Acrylic Console Shield
- Cylinder Bellows
- UL® EE Rating[1]
- Flashing Amber Beacon
- Operator Tool Tray

1. Not available on Multi-powered models.

Dimensions

All dimensions are approximate.





A.Platform Size

E300AJ	30 x 48 in.	0.76 x 1.22 m
E300AJP	30 x 48 in.	0.76 x 1.22 m
E400AN	30 x 48 in.	0.76 x 1.22 m
E/M400AJP	30 x 60 in.	0.76 x 1.52 m
E/M400AJPN	30 x 48 in.	0.76 x 1.22 m
E450A	30 x 60 in.	0.76 x 1.52 m
E/M450AJ	30 x 60 in.	0.76 x 1.52 m

B. Overall Width

E300AJ	4 ft	1.22 m
E300AJP	4 ft	1.22 m
E400AN	4 ft 11 in.	1.5 m
E/M400AJP	5 ft 9 in.	1.75 m
E/M400AJPN	4 ft 11 in.	1.5 m
E450A	5 ft 9 in.	1.75 m
E/M450AJ	5 ft 9 in.	1.75 m

C. Tailswing

E300AJ	Zero	
E300AJP	Zero	
E400AN	4 in.	10 cm
E/M400AJP	Zero	
E/M400AJPN	4 in.	10 cm
E450A	Zero	
E/M450AJ	Zero	

D. Stowed Height

E300AJ	6 ft 7 in.	2.01 m
E300AJP	6 ft 7 in.	2.01 m
E400AN	6 ft 5.75 in.	1.97 m
E/M400AJP	6 ft 7 in.	2.01 m
E/M400AJPN	6 ft 5.75 in.	1.97 m
E450A	6 ft 6 in.	1.98 m
E/M450AJ	6 ft 7 in.	2.01 m

E. Stowed Length

E300AJ	18 ft 2 in.	5.54 m
E300AJP	18 ft 10 in.	5.74 m
E400AN	18 ft 1 in.	5.51 m
E/M400AJP	22 ft	6.71 m
E/M400AJPN	22 ft	6.71 m
E450A	19 ft 1 in.	5.82 m
E/M450AJ	21 ft 2 in.	6.45 m

F. Wheelbase

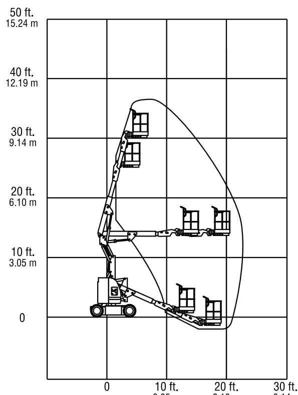
E300AJ	5 ft 5 in.	1.65 m
E300AJP	5 ft 5 in.	1.65 m
E400AN	6 ft 7 in.	2.01 m
E/M400AJP	6 ft 7 in.	2.01 m
E/M400AJPN	6 ft 7 in.	2.01 m
E450A	6 ft 7 in.	2.01 m
E/M450AJ	6 ft 7 in.	2.01 m

G. Ground Clearance

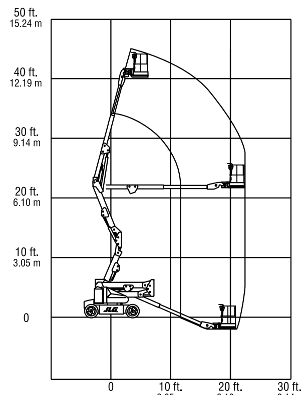
E300AJ	4 in.	10 cm
E300AJP	4 in.	10 cm
E400AN	5 in.	13 cm
E/M400AJP	8.5 in.	22 cm
E/M400AJPN	5 in.	13 cm
E450A	8.5 in.	22 cm
E/M450AJ	8.5 in.	22 cm

Reach Diagrams

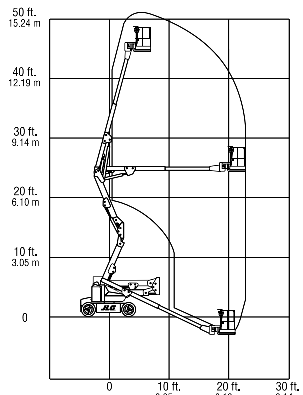
E300



E400



E450



JLG

The JLG "1 & 5" Warranty

We provide coverage for one (1) full year, and cover all specified major structural components for five (5) years. Due to continuous product improvements, we reserve the right to make specification and/or equipment changes without prior notification. This machine meets or exceeds applicable ANSI and CSA requirements based on machine configuration as originally manufactured for intended applications. Please reference the serial number plate on the machine for additional information.

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APPENDIX C
GEOTECHNICAL REPORT

Soils & Engineering Services, Inc.

June 3, 2019 Project 13249

Mr. Ron Bernhagen
Pierce Engineers, Inc.
181 N. Broadway
Milwaukee, Wisconsin 53202

Subject: Report of Soil Sampling and Testing
Structural Materials Testing - Show Dome
Mitchell Park Horticultural Conservatory
Milwaukee, Wisconsin
Pierce Engineers Project No. 19074

Dear Mr. Bernhagen:

On May 16, 2019, we were at the subject site, at your request, to perform field testing on materials exposed at each of two test sites. We understand these sites are where a personnel lift will be placed by others to access the dome structure itself. There is a concern regarding the ability of the existing walkways with concrete pavers to support the weight of the lift. For this report, we refer to the two areas as Location #1 and Location #2.

We understand that the staff at the Horticultural Conservatory routinely uses a JLG Model E400AJPN/M400AJPN lift. This lift has a rated overall weight of 13,700 pounds and a ground bearing pressure of 185 pounds per square inch (psi). We understand that this lift was used on the site the week of May 6, 2019, without plywood covering the walkway pavers. The proposed lift consists of a Model E450AJ/M450AJ with a rated overall weight of 14,400 pounds, and a ground bearing pressure of up to 110 psi.

At the time of arrival of our technician on the project site, the pavers in each of the two test areas had been removed by Arteaga Construction. We used a hand auger, steel push rod, and a nuclear density test gauge to observe and test the soils encountered at each test area. We used a nuclear density test gauge to obtain moisture and density readings with the probe in back scatter mode and then with the probe at 12 inches of depth, per ASTM Designation D2922. We obtained bulk samples of the soils encountered at each location and tested them in our laboratory to develop a modified Proctor curve per ASTM Designation D1557. The Optimum Moisture / Maximum Density Test Report for the three soil types tested are provided on enclosed Figure 1, 2 and 3.

Location 1

This location consisted of light-brown fine to medium sand, little gravel, little silt extending from the grade of the bottom of the pavers to a depth of 1 inch. Below this sand layer was a 4-inch-thick layer of crushed aggregate base course over 14 inches of brown silty fine sand with gravel over 6 inches of dark brown sandy clay over 5 inches of clear 3/4-inch stone over fine to medium sand. We terminated the hand auger boring at a depth of 48 inches below the top of the sand layer.

The field density test results are summarized as follows.

Density Gauge Probe Setting	Dry Density (pcf)	Maximum Density	Percent Density
Backscatter	123.8	137.8	90.0
12 inches	131.4	139.7	94.1

The push probe penetrated the soils approximately 1 to 1.5 inches in the upper 5 inches of the soil and penetrated 4 inches at 19 inches of depth.

Location 2

This location consisted of tan fine to medium sand extending from the grade of the bottom of the pavers to a depth of 1 inch. Below this sand layer was a 3-inch-thick layer of fine to medium sand, some gravel, some silt, over a 2-inch-thick layer of crushed aggregate base course over 18 inches of brown fine to medium sand, some clay, some silt over brown fine to medium sand, some gravel to 36 inches. The lower soil consisted of tan fine to medium sand, little gravel to the maximum depth of 48 inches for the hand auger boring.

The field density test results are summarized as follows.

Density Gauge Probe Setting	Dry Density (pcf)	Maximum Density	Percent Density
Backscatter	114.6	135.3	84.7
12 inches	122.7	135.3	90.7

The hand probe penetrated the soils approximately 0.5 to 1.0 inches in the upper inch of the test site, 3 to 4 inches at 12 inches of depth, and 1 to 3 inches at 24 inches of depth.

Based on the anticipated weight of the personnel left, the prior use of a lift with a higher ground bearing pressure, and the results of our field testing, we recommend placing two layers of 1/2-inch-thick plywood on the walkway to distribute the load over a larger area than the tires, only.

If you have any questions concerning this submittal, or if we can be of further assistance, please contact us.

Respectfully submitted,

SOILS & ENGINEERING SERVICES, INC.

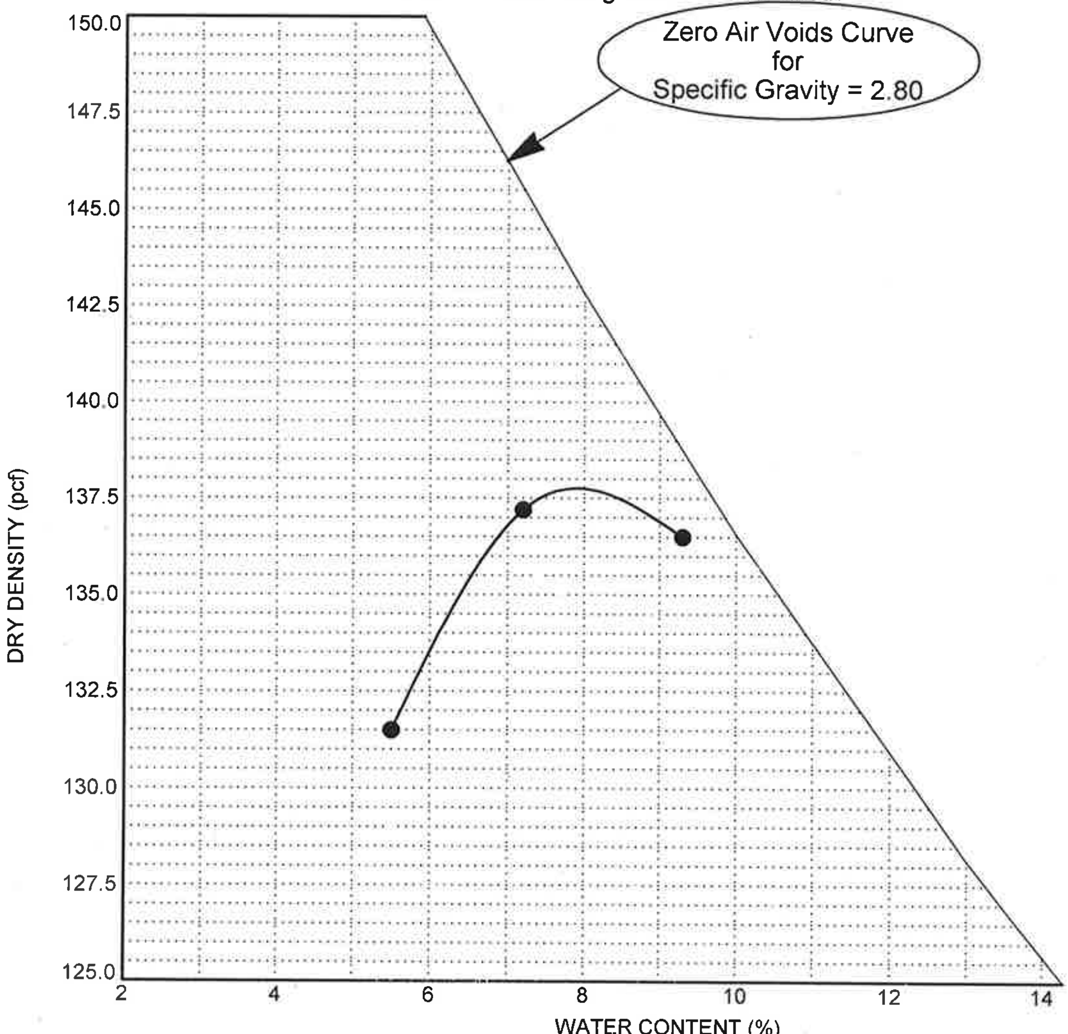
Duane E. Reichel

Duane E. Reichel, P.E.

DER:JAJ:wsr

OPTIMUM MOISTURE / MAXIMUM DENSITY TEST REPORT

ASTM Test Designation D1557 Method C



Laboratory Maximum Dry Density* = **137.8** pcf at Optimum Moisture = **7.8** %

*Laboratory Maximum Dry Density determined for material passing the $^3/_4$-inch sieve using a mechanical rammer with a pie-shaped face.

Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index	Percent Material Retained 3/4"	Percent Material Retained 3/8"	Percent Material Retained #4	Percent Material Passing #200
—	—	—	—	—	—	—	—

Remarks
Location 1, 1" to 5" Depth

Sample Name
Sample 1, SES Sample 1612 {obtained 5/16/2019}

Sample Classification
GRAVEL WITH SILT AND SAND (GM/SM) *— fine to medium grained, non-plastic to low plasticity fines, light brownish-gray*

Soils & Engineering Services, Inc.
1102 STEWART STREET • MADISON, WISCONSIN 53713
Phone: 608-274-7600 • 888-866-SOIL (7645)
Fax: 608-274-7511 • Email: soils@soils.ws
CONSULTING CIVIL ENGINEERS SINCE 1966

LABORATORY TEST RESULT RECORD
Mitchell Park Domes
524 South Layton Boulevard
City of Milwaukee, Milwaukee County, Wisconsin

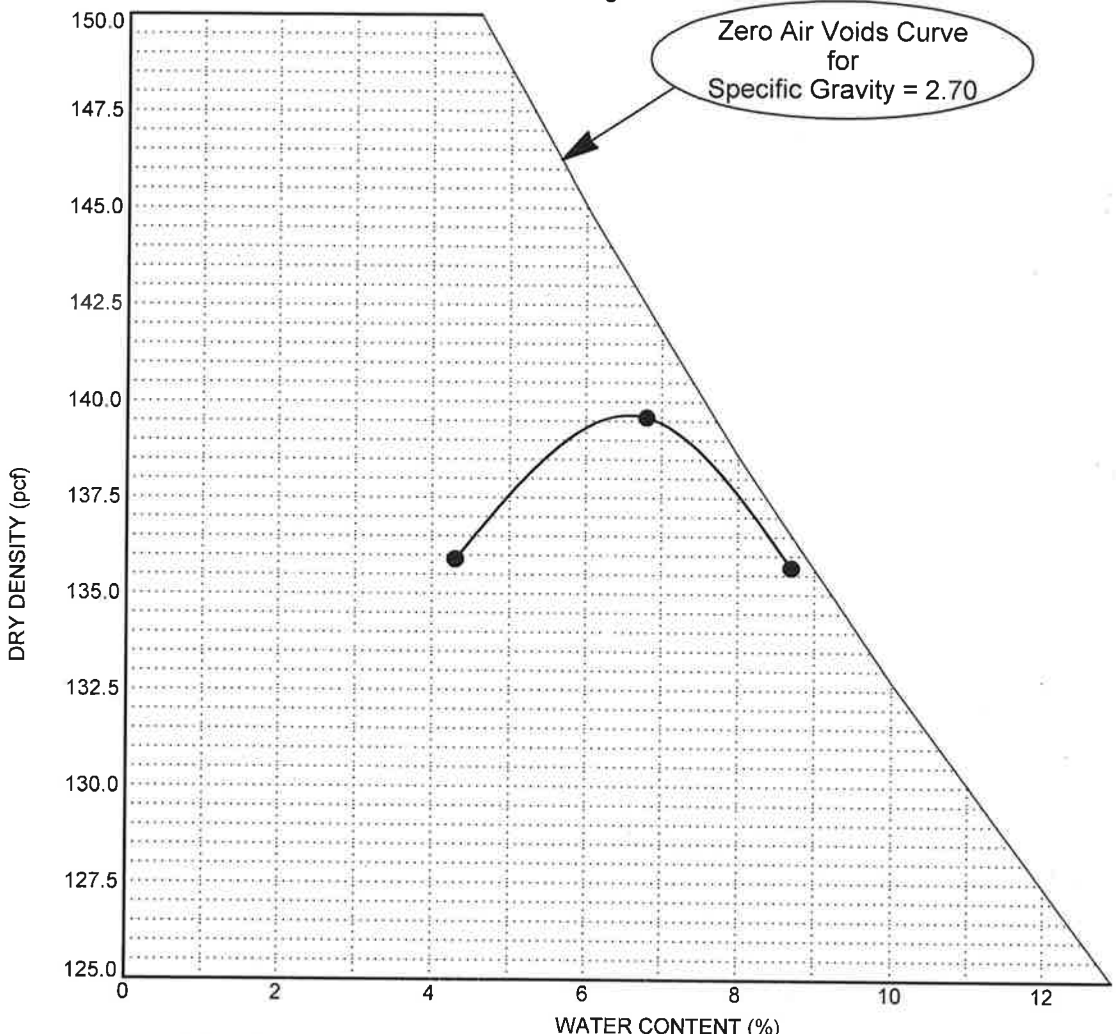
13249

FIGURE 1

Printed on 5/24/2019

OPTIMUM MOISTURE / MAXIMUM DENSITY TEST REPORT

ASTM Test Designation D1557 Method C



Laboratory Maximum Dry Density* = **139.7** pcf at Optimum Moisture = **6.5** %

*Laboratory Maximum Dry Density determined for material passing the $^{3}/_{4}$-inch sieve using a mechanical rammer with a pie-shaped face.

Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index	Percent Material			
				Retained			Passing
				3/4"	3/8"	#4	#200
—	—	—	—	—	—	—	—

Remarks
Location 1, 5" to 19" Depth

Sample Name
Sample 2 **SES Sample 1613 {obtained 5/16/2019}**

Sample Classification
SILTY SAND WITH GRAVEL (SM) — *fine to medium grained, non-plastic to low plasticity fines, brownish-gray*

Soils & Engineering Services, Inc.
1102 STEWART STREET • MADISON, WISCONSIN 53713
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LABORATORY TEST RESULT RECORD
Mitchell Park Domes
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City of Milwaukee, Milwaukee County, Wisconsin

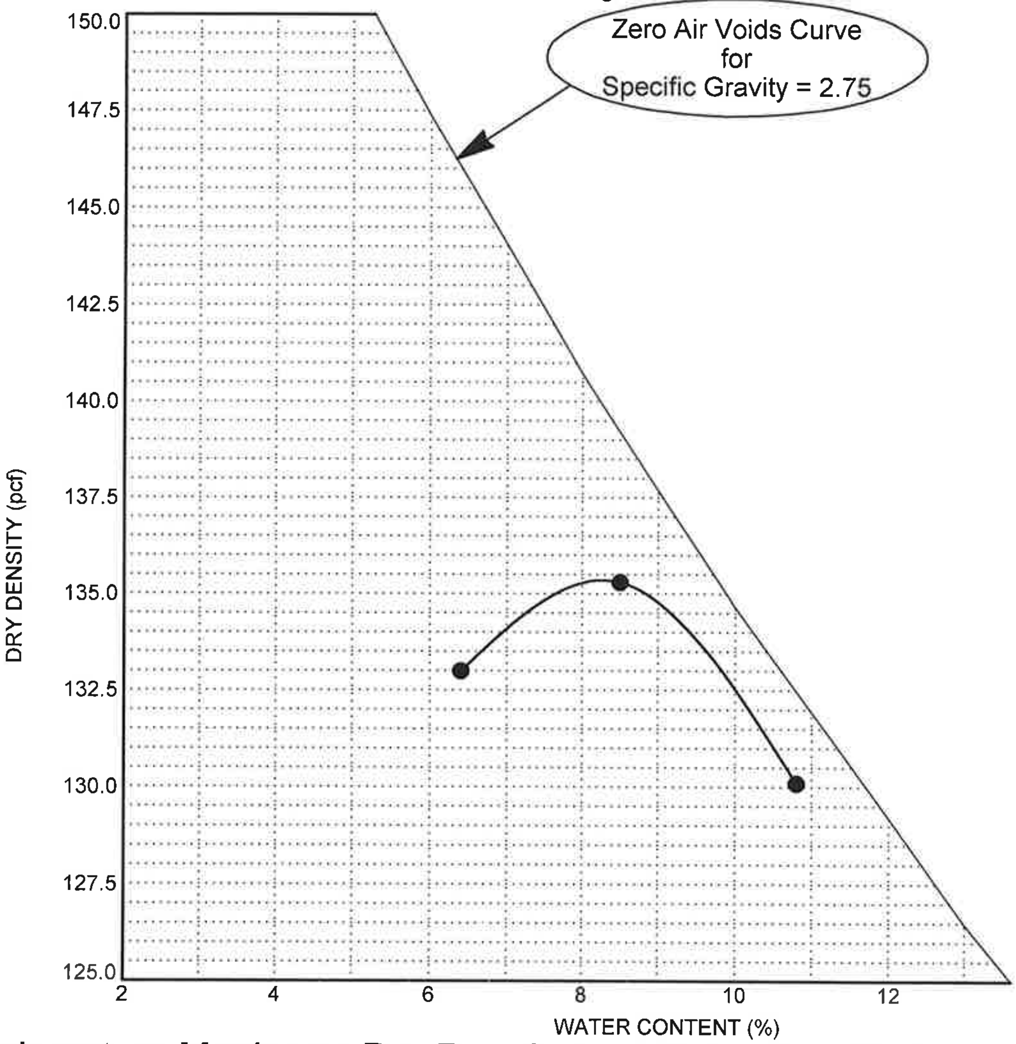
13249

FIGURE 2

Printed on 5/24/2019

OPTIMUM MOISTURE / MAXIMUM DENSITY TEST REPORT

ASTM Test Designation D1557 Method B



Laboratory Maximum Dry Density* = **135.3** pcf at Optimum Moisture = **8.3** %

*Laboratory Maximum Dry Density determined for material passing the $^{3}/_{8}$-inch sieve using a mechanical rammer with a circular face.

Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index	Percent Material Retained 3/4"	Percent Material Retained 3/8"	Percent Material Retained #4	Percent Material Passing #200
—	—	—	—	—	—	**13**	—

Remarks
Location 2, 1" to 12" Depth

Sample Name
Sample 3 **SES Sample 1614 {obtained 5/16/2019}**

Sample Classification
***SILTY SAND WITH GRAVEL (SM)** — fine to medium grained, non-plastic to low plasticity fines, grayish-brown*

Soils & Engineering Services, Inc.
1102 STEWART STREET • MADISON, WISCONSIN 53713
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LABORATORY TEST RESULT RECORD
Mitchell Park Domes
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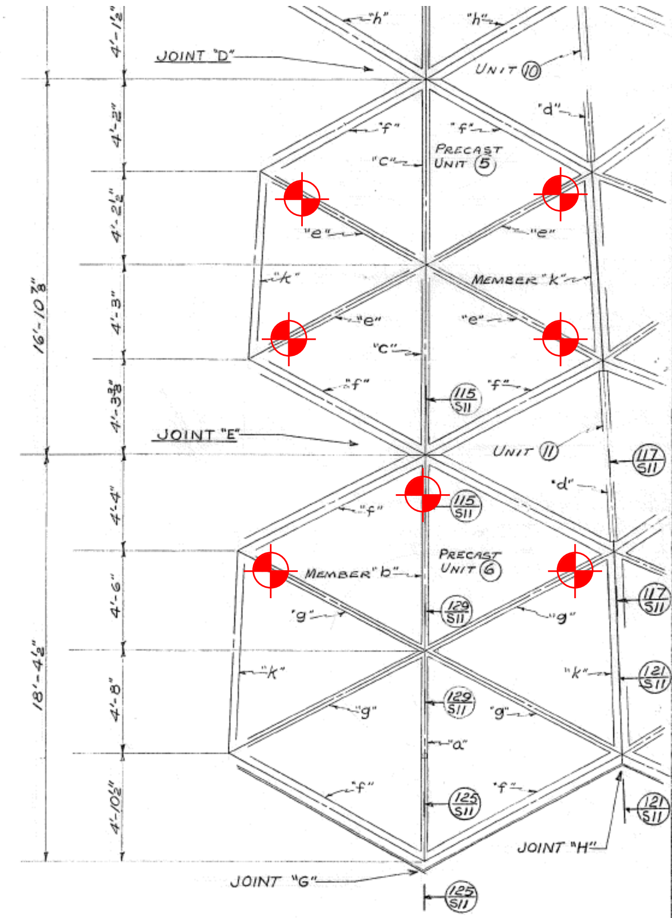
City of Milwaukee, Milwaukee County, Wisconsin

13249

FIGURE 3

APPENDIX D
SURVEY TARGET LOCATIONS
MONITORING SURVEY RESULTS



locate target 18" off nodes

TYPICAL PRECAST UNITS 1 TO 11 INCLUSIVE FOR DOME ASSEMBLY

SCALE: 1/4" = 1'-0"

SEE JOINT DETAILS FOR ASSEMBLY.
SEE SHEETS S-12, S-13, S-14 FOR DETAILS AT ENTRANCES.

Mitchell Dome Monitoring Survey

(FN: BSE2164)

NOTES:

1) Coordinates and elevations are based upon an assumed datum.

2) Units are in feet.

Target Numbering System

	Area 1			Area 2	
1		7	8		14
2		6	9		13
	4			11	
3		5	10		12

WISCONSIN
FRANK J. LAPACEK
S-2658
Poynette
WI
06-04-19
LAND SURVEYOR

5/24/2019

AREA 1

	northing	easting	elevation	
1	4983.202	4937.922	128.188	TARGET
2	4983.307	4934.774	122.059	TARGET
3	4983.560	4930.942	112.882	TARGET
4	4990.243	4933.193	116.253	TARGET
5	4997.341	4933.726	112.918	TARGET
6	4996.205	4937.334	122.056	TARGET
7	4995.186	4940.351	128.257	TARGET

AREA 2

8	5030.490	4970.204	128.172	TARGET
9	5033.270	4968.603	122.042	TARGET
10	5036.623	4966.911	112.910	TARGET
11	5038.349	4973.733	116.270	TARGET
12	5041.630	4979.898	112.882	TARGET
13	5037.944	4980.864	122.155	TARGET
14	5034.869	4981.530	128.217	TARGET

Movement is negligible as shown in the "Change" column below.

6/3/2019

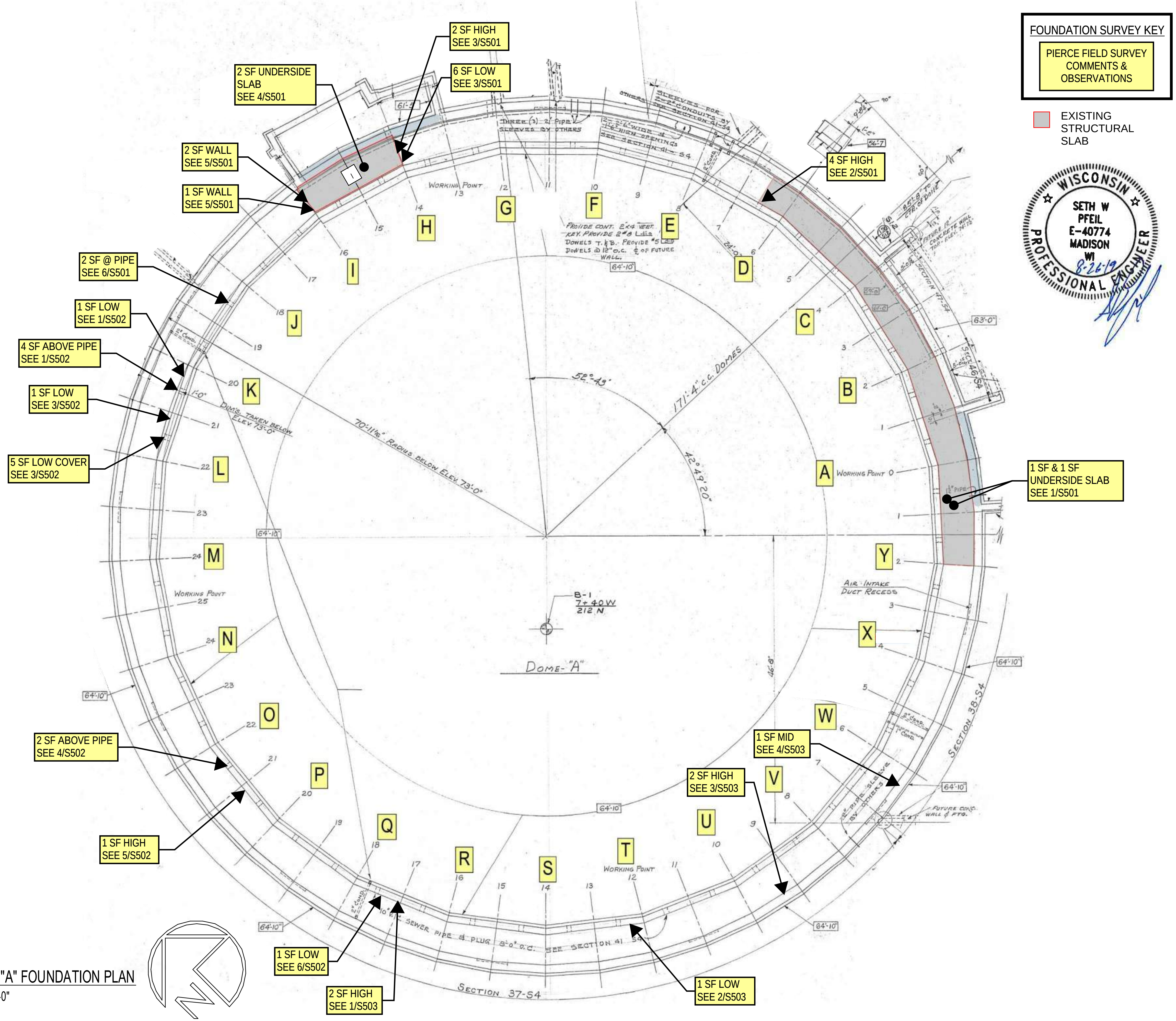
Area 1

	northing	easting	elevation		Change northing	Change easting	Change elevation
1	4983.207	4937.918	128.192	TARGET	0.004	-0.004	0.004
2	4983.309	4934.771	122.061	TARGET	0.002	-0.003	0.002
3	4983.561	4930.937	112.885	TARGET	0.001	-0.005	0.003
4	4990.244	4933.187	116.254	TARGET	0.001	-0.006	0.001
5	4997.343	4933.726	112.921	TARGET	0.002	0.000	0.003
6	4996.207	4937.328	122.059	TARGET	0.002	-0.006	0.003
7	4995.189	4940.353	128.257	TARGET	0.003	0.002	0.000

Area 2

8	5030.489	4970.204	128.174	TARGET	-0.001	-0.001	0.002
9	5033.269	4968.602	122.044	TARGET	0.000	0.000	0.003
10	5036.623	4966.911	112.912	TARGET	0.000	0.000	0.002
11	5038.348	4973.735	116.272	TARGET	-0.001	0.002	0.002
12	5041.632	4979.897	112.883	TARGET	0.002	-0.001	0.002
13	5037.944	4980.866	122.158	TARGET	-0.001	0.001	0.002
14	5034.868	4981.530	128.219	TARGET	0.000	0.000	0.002

APPENDIX E
FOUNDATION CONDITION SURVEY & PHOTOS



1 S101 SHOWDOME "A" FOUNDATION PLAN
SCALE: 1/16" = 1'-0"

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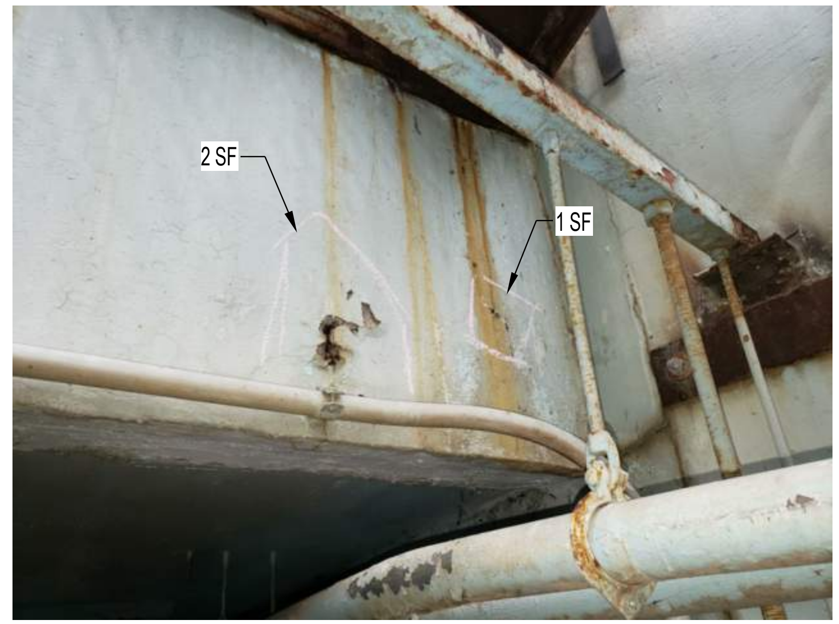
PROJECT No: 19074
DRAWN BY: PE
ISSUE DATE: 06/27/2019
SHEET NAME:
SHOWDOME "A" FOUNDATION PLAN
SHEET NUMBER:
S101

6
S501
J -K - 2 SF GROUT @ PIPE



5
S501
I - 1 SF & 2 SF

4
S501
H-I - 2 SF US SLAB

3
S501
H - 6 SF & 2 SF

2
S501
D-E - 4 SF HIGH WALL

1
S501
Ø-A - 1 SF & 1 SF UNERSIDE SLAB

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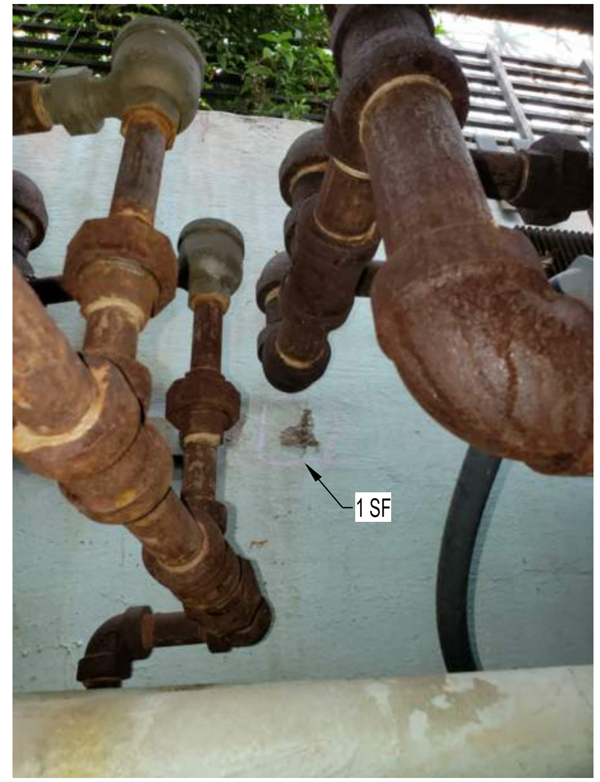
PROJECT No:	19074
DRAWN BY:	PE
ISSUE DATE:	06/27/2019
SHEET NAME:	RESTORATION PHOTOS
SHEET NUMBER:	S501

6
S502
Q-R - 1 SF LOW



5
S502
P-Q - 1 SF HIGH

4
S502
O-P - 2 SF GROUT @ PIPE

3
S502
K-L 5 SF LOW COVER

2
S502
K-L - 1 SF LOW

1
S502
J-K - 2 SF @ PIPE PENETRATION

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PROJECT No: 19074
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ISSUE DATE: 06/27/2019
SHEET NAME:

RESTORATION PHOTOS

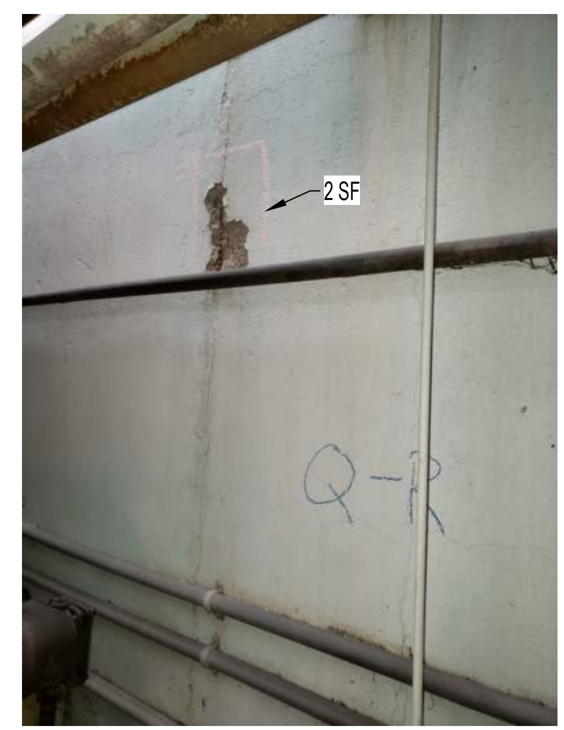
SHEET NUMBER:

S502

4 S503 V-W - 1 SF MID

3 S503 U-V - 1 SF HIGH

2 S503 S-T - 1 SF LOW



1 S503 Q-R - 2 SF HIGH

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ISSUE DATE: 06/27/2019
SHEET NAME:
RESTORATION PHOTOS

SHEET NUMBER:
S503

APPENDIX F
VCS PRECAST TESTING REPORT

VECTOR CORROSION SERVICES, INC.
8413 Laurel Fair Circle, Ste 200B, Tampa, FL 33610
Main: 813-501-0050 | Fax: 813-501-1412
eMail: Info@VCServices.com

NDT Corporation, LLC
153 Clinton Road
Sterling, MA 01564
(978) 563-1327

MITCHELL PARK HORTICULTURAL CONSERVATORY
MILWAKEE, WISCONSIN
PRECAST CONCRETE FRAME TESTING

Prepared for:
Ron Bernhagen
Pierce Engineers

Prepared by:
Matt Miltenberger, P.E. - Vice President for Vector Corrosion Services, Inc.
Keith Holster – Operations Manager for NDT Corporation

Reviewed by:
Dr. Brian Pailes, P.E.
Principal Engineer for Vector Corrosion Services, Inc.

VCS Project Number – F19034WI
Revision 1 - August 22, 2019
Enlarge Figure Keys / Legends to improve readability

Introduction

The Mitchell Park Horticultural Conservatory Complex consists of three conoidal domes (the Show Dome, the Tropical Dome and the Arid Dome), a central lobby and attached greenhouses. The domes were constructed between 1959 and 1967 using precast concrete beams connected by weld plates into triangular shapes. This concrete framing supports a network of aluminum framing members with wire-glass glazing. The aluminum framing is attached to the concrete at weld plates located at the beam intersections "nodes" and midpoints of each member.

Over time, the glazing seals have deteriorated, glass has cracked, and leaks have developed in the glazing. Condensation and leaks reaching the weld plates used to attach the glazing to the concrete has caused corrosion and spalling of the adjacent concrete, resulting is small concrete chunks falling from above. This spalling is a safety hazard for the public, so significant effort was taken to inspect and sound each weld plate (1730/dome), remove any loose concrete, and patch exposed reinforcing. As an extra precaution, a stainless steel "chicken wire" netting was installed on the interior of the concrete frame to catch spalls before they reach the pedestrian walkways.

Recent facility planning efforts have identified several options to address the deterioration of the glazing. Modern glazing extrusions are not compatible with the existing system, so replacement is being considered in most of the options. Pierce Engineers was hired by Milwaukee County to identify the overall structural condition of the concrete framing elements and to estimate the remaining service life of the concrete frame. As part of the Pierce Engineering Team, Vector Corrosion Services (VCS) was subcontracted to perform a corrosion and material evaluation. NDT Corporation was also engaged to conduct a non-destructive evaluation of the concrete elements to inform the structural frame analysis of the Show Dome. The intent of this materials evaluation is to conduct a representative sampling of the structural concrete frame to inform future rehabilitation strategies. The rehabilitation options being considered focus on modernizing the glazing system. Most of these glazing options require structural support from the existing concrete space frame. Therefore, determining the condition and remaining service life of the existing concrete framing and foundation is necessary information for the facility planning process.

The focus of the evaluation reported herein was to identify the extent of concrete deterioration that cannot be observed through tactile inspection alone. This includes corrosion activity, concrete degradation, concrete strength, condition of grout pockets, and weld plates. A tactile inspection can identify the structures' current physical condition (e.g. cracked and spalled concrete) while a materials and corrosion evaluation can identify what areas are currently corroding and will lead to physical damage in the future. The objective of this evaluation was to identify the root cause of the deterioration, the extent of damage beyond the visual assessment, and to provide the information necessary to design lasting and effective repairs.

Test Methods & Results

This section describes the methods used by VCS and NDT Corporation to investigate the Show Dome concrete framing during May 28 through May 31, 2019 along with the results from those methods. A detailed discussion regarding each result is provided along with conclusions and recommendations.

Two representative areas of the Show Dome were evaluated – they were located at the base of Sectors M and Q. The locations of sectors were identified in the 2015 report by GRĀEF. The typical sector shapes and connection details were identified in the original structural drawings on Sheet S-11.

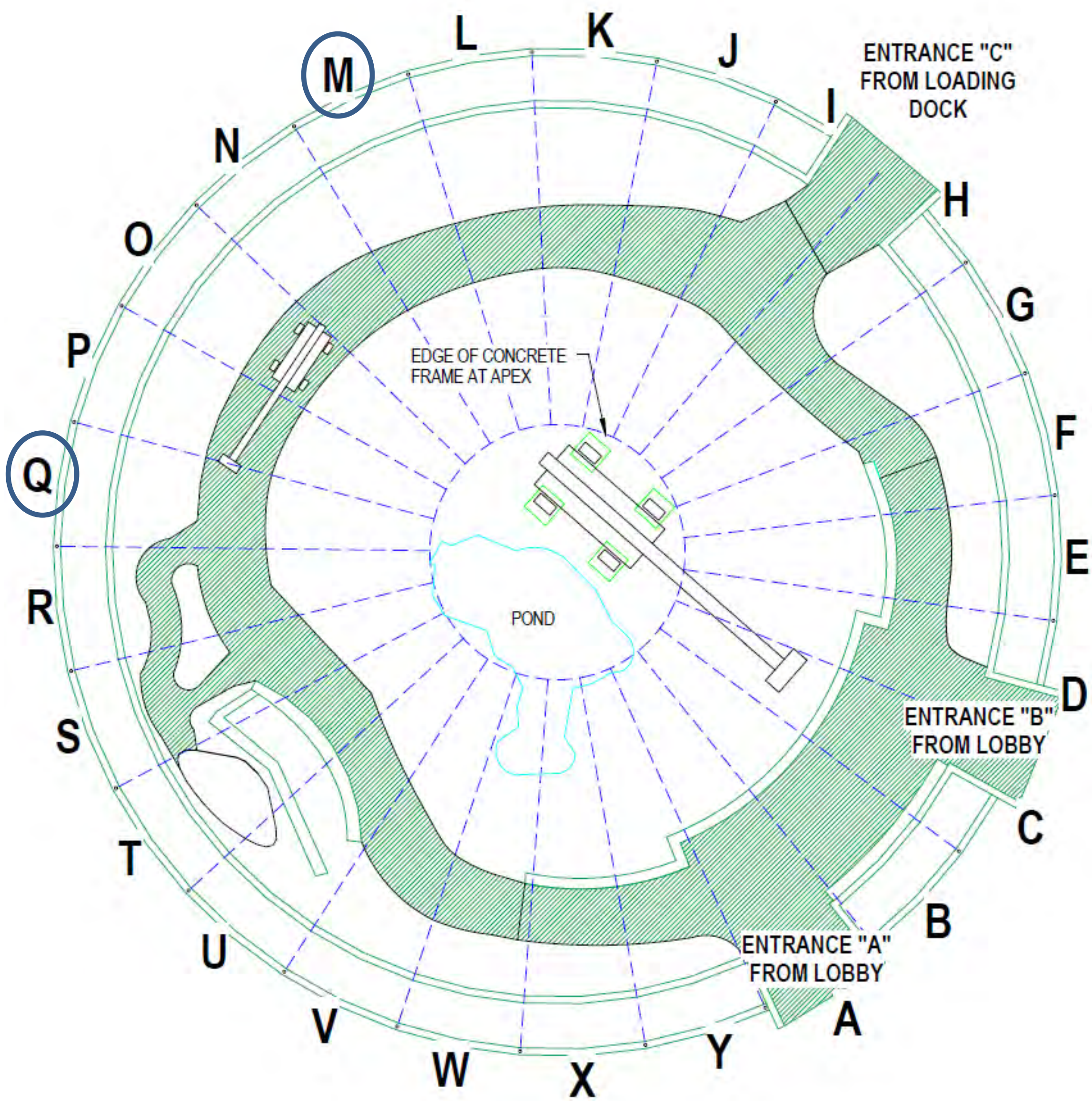


Figure 1: Sector Layout

The naming convention used within the representative test areas is presented in Figure 2. A letter designation was used to identify the 12 weld plate joints, while a number designation was used for the 23 structural units evaluated in each representative test area.

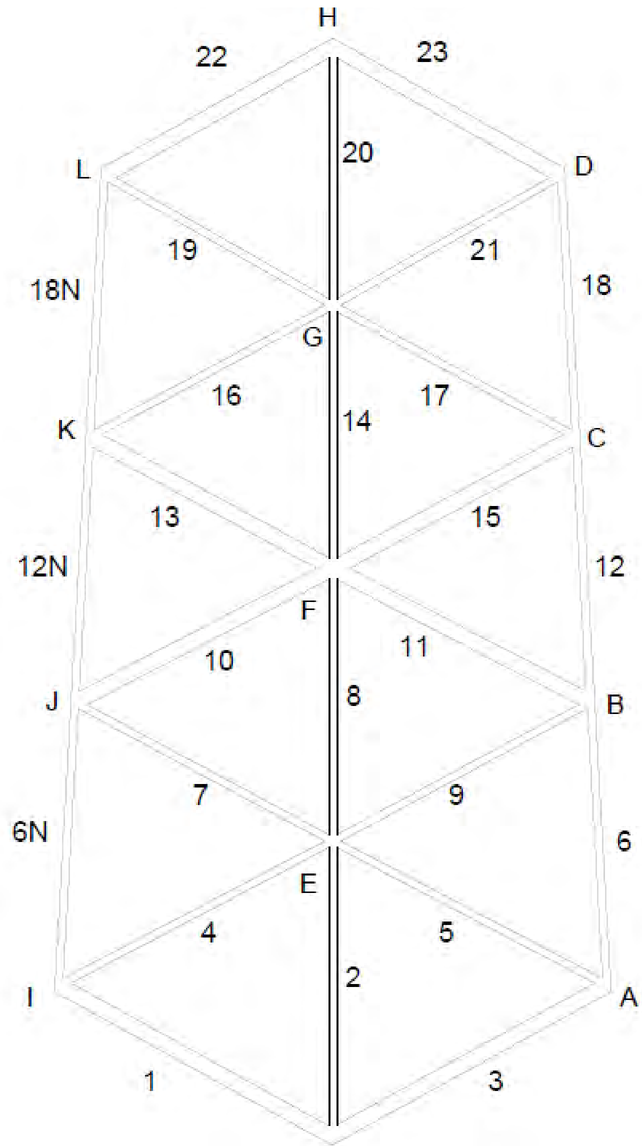


Figure 2: Test Location Key for Area M, (Area Q is similar) Show Dome

Ground Penetrating Radar Survey

Ground penetrating radar (GPR) is a quick and effective way of identifying the location and depth of metal objects within reinforced concrete. Steel reinforcement can be easily identified in a GPR scan due to the significant difference in the electromagnetic properties of steel and concrete. As a result, the location and depth of steel elements (i.e. cover-depth) in concrete can be determined accurately and efficiently.

Cover-depth is an important factor in determining the service life of a reinforced concrete structure. There is a correlation between cover-depth and concrete durability; a reduced cover-depth exponentially impacts the durability of reinforced concrete structures. Inadequate cover-depth allows contaminates and moisture to reach the embedded steel much faster, which in turn initiates corrosion activity earlier in the structure’s life. Inadequate cover-depth is also associated with early-age cracking, which provides a direct path for corrosive agents to attack the steel.

GPR scans were performed at random locations within Areas M and Q. The measured cover-depths ranged from 0.1 inches to 2.3 inches, with an average cover-depth of 0.9 inches and a standard deviation of 0.6 inches. This indicates that in most locations the cover-depth in the concrete beams is between 0.3 to 1.5 inches. The design cover depth should be 0.75 inches.

Electrical Continuity

Electrical continuity of the reinforcing is necessary for possible future corrosion mitigation by cathodic protection and to conduct efficient corrosion potential measurements. In most cast-in-place reinforced concrete structures conventional reinforcement is electrically continuous due to the crossing of bars and tie wires. If the reinforcement is found to be electrically isolated then continuity bonds will be required for the implementation of cathodic protection (CP). Electrical continuity is verified by contacting various steel elements with the lead wires from a high impedance multi-meter using the DC millivolts and/or resistance settings. As per ACI 222R-01 Standard in Section 4.3.1.6a, if the potential difference between the reinforcing elements is less than one (1.0) mV, or one (1.0) ohms, then the reinforcing steel is deemed electrically continuous.

Electrical continuity was measured between the reinforcement within the same concrete beam and between beams across the weld plates. All reinforcement was found to be electrically continuous. If a form of CP were to be applied to the Dome concrete frame, a more robust evaluation of electrical continuity would be required during the construction phase of the CP. However, it is expected that the construction process indicated on the drawings (welding the reinforcing at each intersection; and wire ties between the two bars in each beam) would require very few continuity corrections.

Corrosion Potential Survey

To identify locations with a high probability of active corrosion, corrosion potential measurements were collected in Areas M and Q in accordance with ASTM C876 *Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete* using a copper/copper sulfate (CSE) reference electrode. To collect corrosion potential measurements, the CSE reference electrode is placed on the concrete surface with a saturated sponge used to make an electrical couple with the concrete. The reference electrode is then connected to the negative terminal of a volt-meter. The positive terminal of the volt-meter is connected to the embedded reinforcement of the structure under investigation. The magnitude and spatial variation of the measured potentials provides the probability for active corrosion at the testing location.

A generally accepted interpretation of normalized CSE measurements is provided in the appendix of ASTM C876 (Table 1). It is important to understand that the interpretation values provided in ASTM C876 are a general guideline based on values normalized to 72 degrees Fahrenheit, and are not absolute values. These threshold values can shift based on the concentration of moisture and oxygen in the concrete, as well as other environmental factors like temperature.

Table 1: ASTM C867 Interpretation of Data

Corrosion Potential	Probability of Active Corrosion
< -350 mV	90%
- 350 mV to -200 mV	Uncertain
> −200 mV	10%

Corrosion potential measurement were collected on the structural units within M and Q at four locations designated A-D and the measured values are presented in Table 2 and Table 3, respectively. All the measurements were above -350 mV, which indicates a low probability of active corrosion. However, another effective method of interpreting corrosion potential data is to look at the relative change in potential between two adjacent measurements. Significant potential difference (delta or gradient analysis) between two locations indicates a high probability of active corrosion. The delta values were calculated for all the measurements to better assess the probability of corrosion and are included in Table 2 and Table 3. A delta value of 100 mV in 2 ft was used to indicate probable active corrosion. Delta values of 100 mV or higher are highlighted in red in Table 2 and Table 3.

It is clear from the delta analysis that despite low corrosion potential values recorded for all the structural units, there are still some areas with a reasonable probability for active corrosion. These areas of active corrosion were located predominantly at the weld plates where cracking or poorly consolidated grout was observed. The location and direction of the voltage gradients indicates the probability of corrosion as illustrated in Figure 4 and Figure 5.

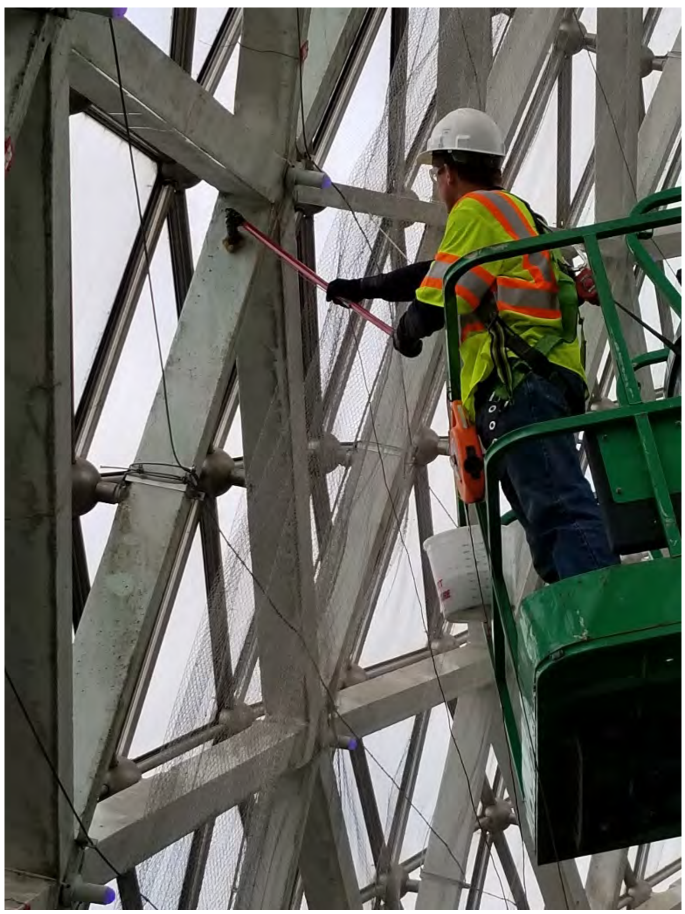


Figure 3: Corrosion Potential Testing

Table 2: Corrosion Potential Values Collected in Area M

	Measured Values				Calculated Delta		
Structural Unit	A (Top)	B	C	D (Bot)	A-B	B-C	C-D
1	-128	-75	obstructed	obstructed	53	obstructed	obstructed
2	-88	14	obstructed	obstructed	102	obstructed	obstructed
3	-130	-108	obstructed	obstructed	22	obstructed	obstructed
4	-50	64	98	-33	114	34	131
5	-56	-12	-24	-130	44	12	106
6	-68	-102	-84	-142	34	18	58
6N	5	28	-48	-71	23	76	23
7	15	69	78	-21	54	9	99
8	-222	24	-27	-9	246	51	18
9	-53	123	65	-59	176	58	124
10	-156	64	100	5	220	36	95
11	-10	100	116	-12	110	16	128
12	-50	5	-42	-20	55	47	22
12N	30	77	147	34	47	70	113
13	-113	36	62	-241	149	26	303
14	-25	-62	-67	-213	37	5	146
15	-63	48	-60	-160	111	108	100
16	26	51	44	-64	25	7	108
17	40	90	-12	-93	50	102	81
18	-37	-117	-105	-145	80	12	40
18N	-1	-15	5	-65	14	20	70
19	-19	69	102	-35	88	33	137
20	38	54	60	-26	16	6	86
21	40	50	63	17	10	13	46
22	33	39	45	8	6	6	37
23	111	100	125	75	11	25	50

Table 3: Corrosion Potential Values Collected in Area Q

	Measured Values				Calculated Delta		
Structural Unit	**A**	**B**	**C**	**D**	**A-B**	**B-C**	**C-D**
1	-74	-80	obstructed	obstructed	6	obstructed	obstructed
2	-37	11	30	obstructed	48	19	obstructed
3	-106	-61	-78	obstructed	45	17	obstructed
4	-28	-30	-39	-64	2	9	25
5	-63	47	25	-18	110	22	43
6	-112	-48	-50	-62	64	2	12
6R	-8	43	32	-19	51	11	51
7	4	107	87	4	103	20	83
8	-120	6	33	17	126	27	16
9	41	74	94	-49	33	20	143
10	-30	125	118	83	155	7	35
11	64	105	66	19	41	39	47
12	-83	2	63	-23	85	61	86
12R	-3	21	33	75	24	12	42
13	-33	77	60	-55	110	17	115
14	84	-26	-17	-60	110	9	43
15	55	75	76	-33	20	1	109
16	127	109	27	-26	18	82	53
17	104	121	84	7	17	37	77
18	13	23	-19	-30	10	42	11
18R	-31	-30	-26	-47	1	4	21
19	77	90	92	105	13	2	13
20	57	43	38	14	14	5	24
21	162	105	95	91	57	10	4
22	101	129	93	91	28	36	2
23	46	81	88	51	35	7	37

It is clear from the gradient analysis illustrated in Figure 4 and Figure 5 that Joint F has the potential for corrosion activity in both test areas. Joint F was selected in both test areas for concrete removal to expose the embedded weld plates.

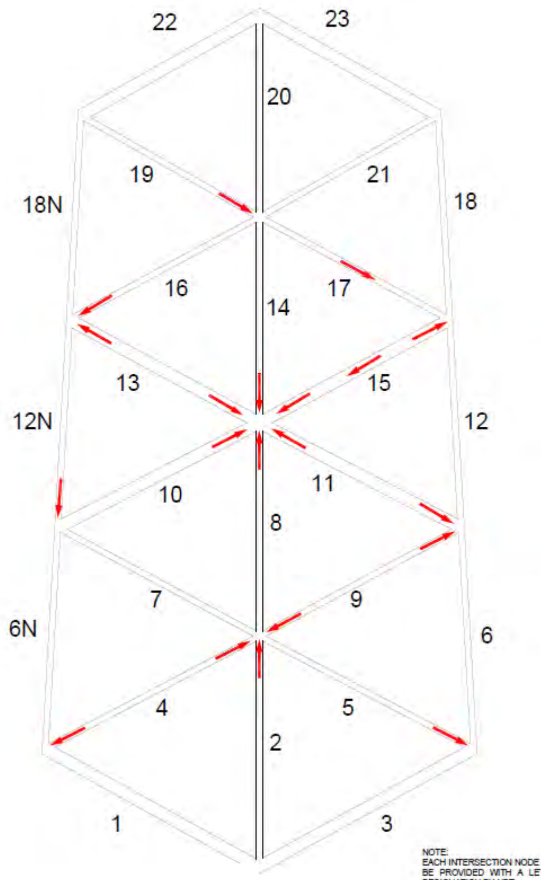


Figure 4: Corrosion Potential Delta Values for Area M

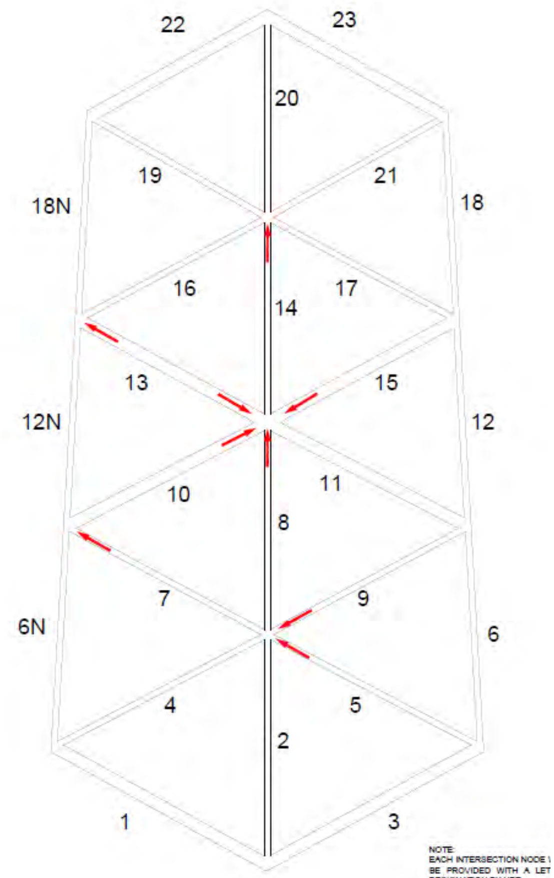


Figure 5: Corrosion Potential Delta Values for Area Q

Sonic/Ultrasonic Measurements

Compressional (P-wave), Shear (S-wave) Wave Velocity Measurements

The sonic/ultrasonic data was acquired with a system designed by NDT Corporation to acquire pulse-velocity (PV) data for concrete condition assessment and flaw detection. This system uses a projectile impact energy source and an array of sensors. This test determines the time required for a compressional and shear wave to travel from the impact point to each of the sensors. Compressional and shear wave velocity values are calculated using the travel times and the distance between the impact point and sensors. Sonic/ultrasonic compressional and shear wave transmission velocity values are used to determine the elastic deformational characteristics of the concrete, including Young's modulus, bulk modulus, and shear modulus values as well as Poisson's ratio. From these values, empirical relationships to compressive strength have been developed (Malhotra, V. M., Carino, N. J. , eds, CRC Handbook on Nondestructive Testing of Concrete, 1991). In general, areas of lower than average velocity indicate areas of weak concrete due to internal cracking, or poor consolidation otherwise known as honey combing; areas of higher than average velocity indicate competent concrete. A more detailed description of the sonic/ultrasonic testing method is provided in Appendix A.

Figure 6: Sonic Testing for Concrete Strength

Sonic/ultrasonic surface measurements were conducted at the quarter point (two locations per member) of each of the structural members 1 through 23 for Element M and Q. Compressive strengths calculated using the stress wave velocity relationship for the structural units tested in elements M and Q are presented in Figure 7 and Figure 8. Locations where the average strength is less than 5,000 psi correspond to lower than average compressional and shear wave velocities and are indicative of increased cracking and deterioration. These locations have been highlighted in orange. Statistical summary of this data is presented in Table 4.

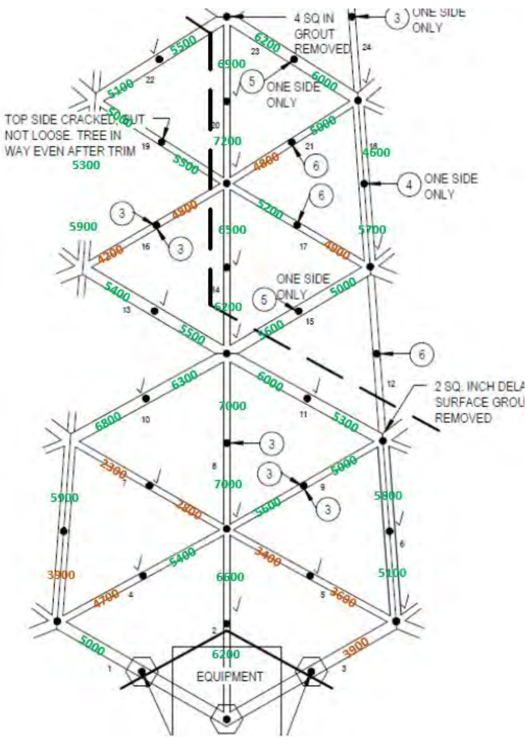


Figure 7: Sonic/Ultrasonic Compressive Strengths Measured in Element M

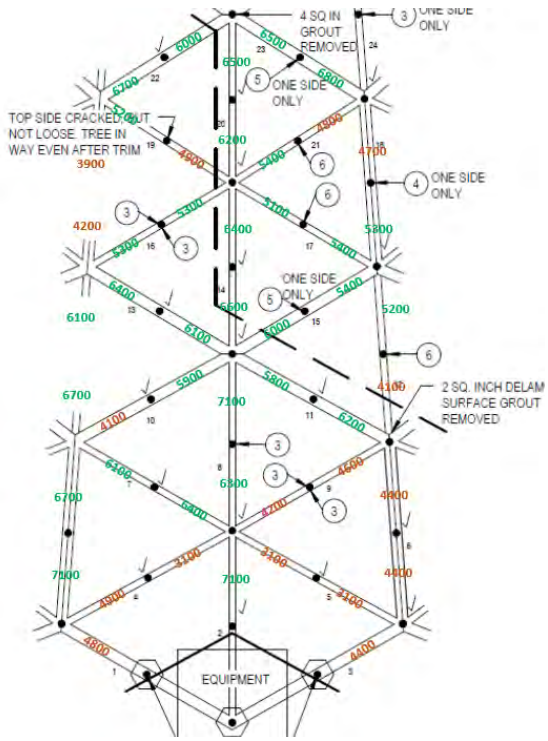


Figure 8: Sonic/Ultrasonic Compressive Strengths Measured in Element Q

Table 4: Sonic/Ultrasonic Compressive Strength Statistics for Precast Concrete Beams

Element	Average Compressive Strength (psi)	Standard Deviation	Minimum Strength (psi)	Maximum Strength (psi)
M	5,500	1,150	2,300	7,400
Q	5,400	1,100	3,100	7,100
Overall	5,500	1,120	2,300	7,400

Overall, the compressive strengths in Areas M and Q were very similar. The average compressive strengths of the concrete beams in each area were both in excess of 5,000 psi, although areas of low compressive strength were identified in both areas. Fracturing or cracking is the primary cause of concrete element weakening. Cracking can occur from over stress, restrained volume change, or deterioration mechanisms such as ASR or corrosion. Cracks can be oriented horizontally below the surface (delaminations), or vertically in a transverse or longitudinal direction or a combination of all of the above. Delaminations (horizontal cracking) commonly occur as a result of water infiltration to the top layer of reinforcing steel, which results in corrosion and swelling of the bars that eventually fractures the concrete. Longitudinal and transverse cracking can occur as a result of loading or restrained volume change. Cracking typically begins as microcracks (undetectable to the naked eye) and progresses to observable macrocracks as the result of continual loading and unloading. This process can be accelerated by water infiltration into the cracks and freeze-thaw cycles, reactive aggregate reactions, or transport of aggressive salts and initiation of corrosion.

In addition to the concrete beams, sonic/ultrasonic measurements were conducted on interior and exterior foundations located directly below Area M, and this data is presented in Table 5. Compressive strengths of interior and exterior foundations were very similar, and no areas of significant strength reduction were observed.

Table 5: Sonic/Ultrasonic Compressive Strength Statistics for Foundations in Element M

Interior Foundation	Compressive Strength (psi)
1	6400
2	6500
3	7400
4	7400
5	7800
6	7900
7	6800
8	6500
9	7500
10	7900
Average	7,200
Standard deviation	600

Exterior Foundation	Compressive Strength (psi)
1	8000
2	8000
3	7900
4	8000
5	8000
6	8000
7	6600
8	7000
9	7000
10	6900
Average	7,500
Standard deviation	580

Waveform Analysis/Signal Quality

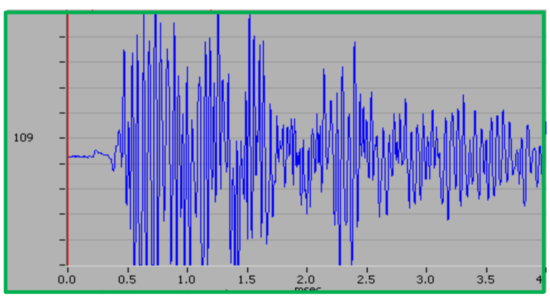
Waveform analysis/signal quality uses the same system designed by NDT Corporation to acquire pulse-velocity data. The sonic/ultrasonic system uses an energy impact source to induce a sharp vibration wave (pulse) into the concrete and receiving sensors record the arrival (time) of the energy wave through the concrete. Using the sensor array with set distances, the compressional and shear wave velocities can be calculated. However, due to field conditions and configuration of the concrete elements this is not always feasible. In these cases, waveform and signal quality can be used for a general qualitative assessment to identify potential internal flaws such as cracking, debonding, delamination, segregation, etc.

Internal flaws (cracking, bonding/de-bonding, delamination, segregation, etc.) which impede the propagation of the energy wave through the concrete not only slow the velocity of the compressional and shear waves but also affect the shape of the waveform. Signal amplitude, attenuation, and frequency content are affected.

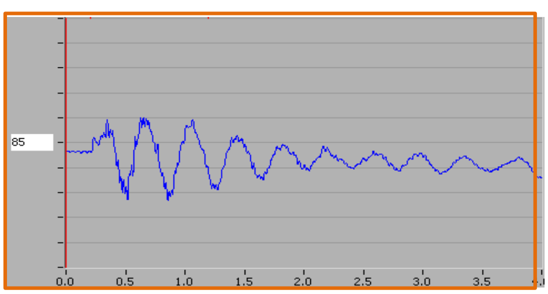
The presence of internal flaws will have the following effects:

1) lower velocity, and lower strength
2) decreased amplitude of the signal
3) disruption of signal attenuation
4) filter high frequencies from the signal

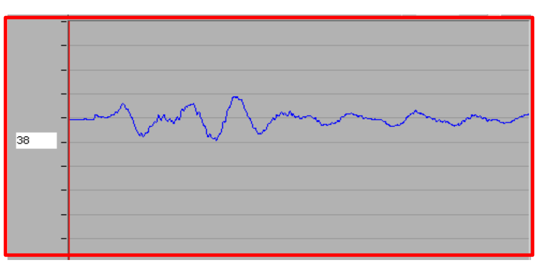
Delaminations or “voiding” may also be detected by the presence of a “drum-head” frequency. The low rolling “drum-head” frequency is caused by the flexing of a “relatively” thin layer of concrete overlaying a void/delamination. The waveforms shown in Figure 9 (data collected on this project) are indicative of these conditions.



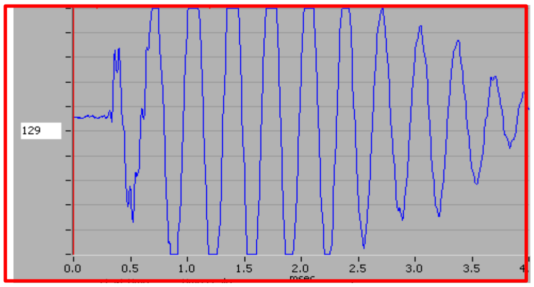
Well-Bonded - Good signal quality
Strong signal amplitude
Good signal attenuation
High frequencies un-filtered



Partial Bonding (cracking/poor grout) - Fair signal quality
Dimininshed signal amplitude
Moderate signal attenuation
High frequencies patially filtered



Poor/no Bonding (cracking/poor grout) - Poor signal quality
Low signal amplitude
Poor signal attenuation
High frequencies filtered



Poor/no Bonding (cracking/poor grout high potential for delamination/voiding)
Poor signal quality
Signal dominated by Low frequency "Drum-head"
Poor signal attenuation
High frequencies filtered

Figure 9: Typical Waveforms and Their Interpretation

Grouted Shear Keys

Surface PV was used to directly measure the compressional wave velocity values through the concrete/grout joint at each of the member intersections (shear keys) A – L to assess the quality of the bond between the concrete and the grout. Three measurements were conducted at each member intersection with the array centered across the grout joint. The configuration for the impact source and sensor location used for the shear key assessment is shown in Figure 11. The test results for all the shear keys in Area M and Q are presented in Figure 12 and Figure 13, respectively. The poor bonding is indicated by the red arrows, partial bonding is indicated by the yellow arrows, and green arrows indicate good bonding.

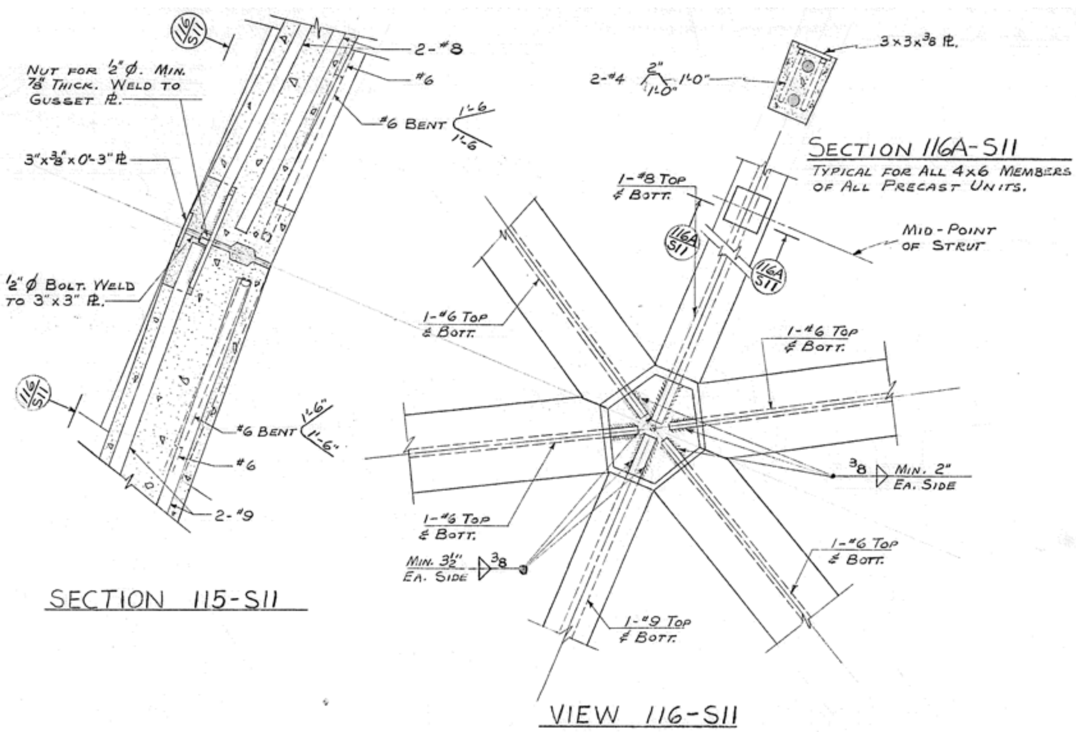


Figure 10: Original Detail at Grouted Weld Plates

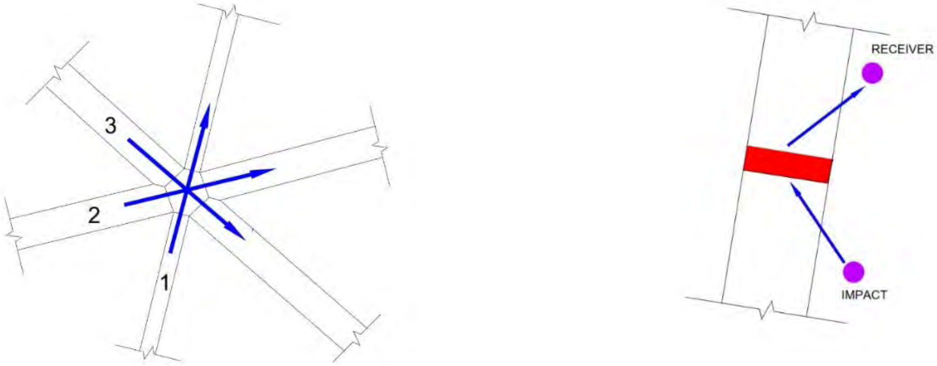


Figure 11: Shear Key Testing Configuration

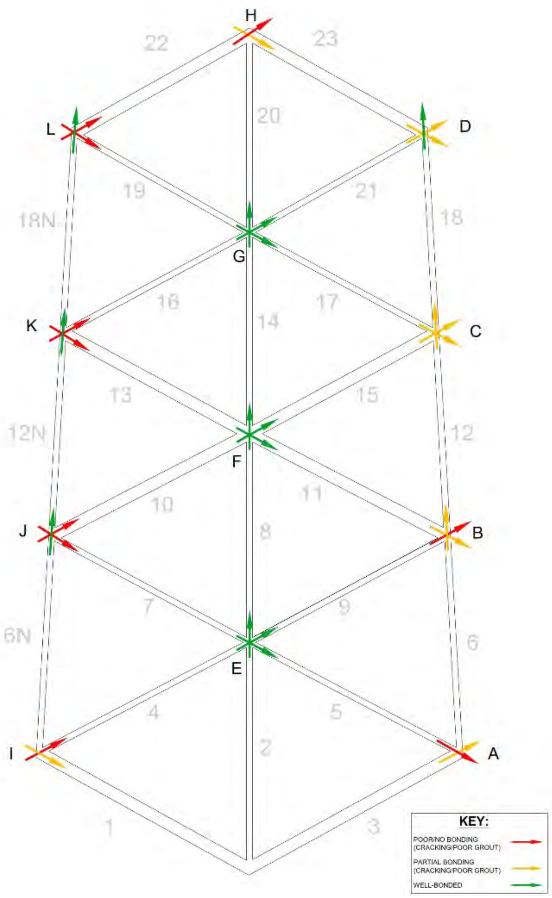


Figure 12: Shear Key Testing of Element M

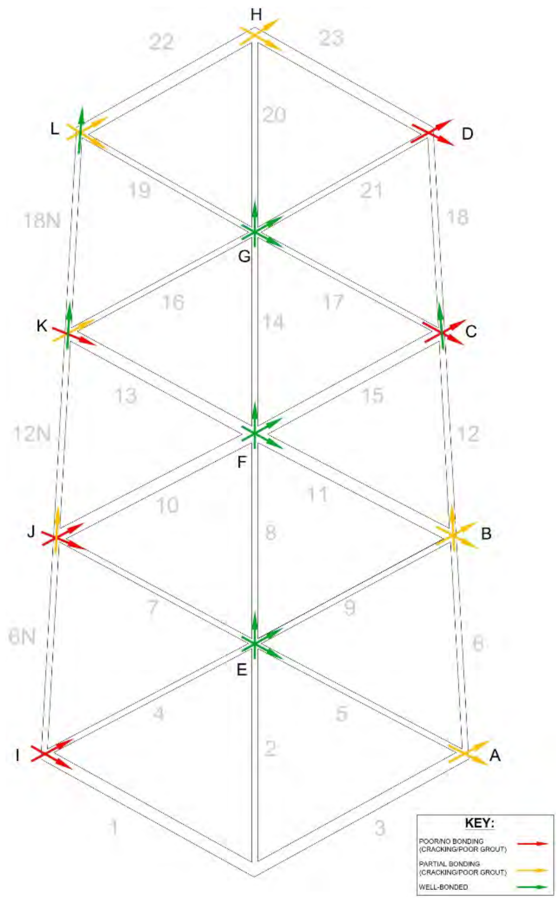
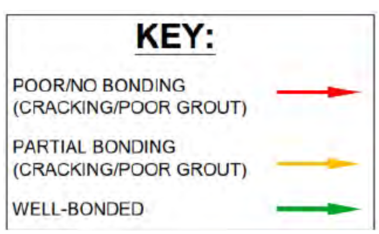


Figure 13: Shear Key Testing of Element Q



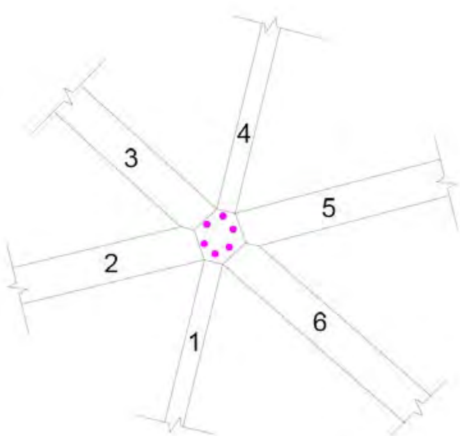
Joints E and G for Areas M and Q do not have grout joints. The measured compressional wave velocities were high and the signal quality was “good” at these locations. The vertical component for joints A, B, C, D, and I, J, K, L did not cross the grout joint for these units and in most cases the compressional wave velocities are high and the signal quality is “good”. A summary of the results is provided in Table 6. Majority of the joints had poor bonding, and only 10% of the joints in Area M and 20% in Area Q were determined to have good bonding.

Table 6: Shear Key Testing Results

Joint	Element M	Element Q
A	Partial Bonding	Partial Bonding
B	Poor/No Bonding	Partial Bonding
C	Partial Bonding	Poor/No Bonding
D	Partial Bonding	Poor/No Bonding
E	N/A	N/A
F	Well-Bonded	Well-Bonded
G	N/A	N/A
H	Poor/No Bonding	Well-Bonded
I	Poor/No Bonding	Poor/No Bonding
J	Poor/No Bonding	Poor/No Bonding
K	Poor/No Bonding	Poor/No Bonding
L	Poor/No Bonding	Partial Bonding
Total Well-Bonded	1 (10%)	2 (20%)
Total Partially Bonded	3 (30%)	3 (30%)
Total Poor Bonding	6 (60%)	5 (50%)

Element Connection Weld Plates

Sonic/ultrasonic measurements of the weld plates were conducted through the member with the high frequency energy source located on one face of the element and the sensor at the same location on the opposing face of the element approximately 1-2 inch from the glazing frame connection as shown in Figure 14. These measurements are intended to provide a general assessment of the internal condition of the grout around and behind the weld plates. Confirmation openings were created at joint F for both Areas M and Q.



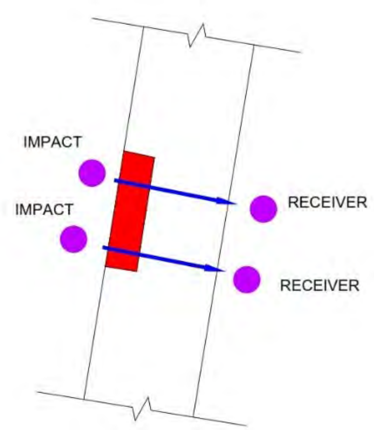


Figure 14: Weld Plate Testing Configuration

The test results are presented in Figure 15 and Figure 16, which are also included in Appendix B in a larger format. Based on signal quality and confirmation openings at Joint

F for both Element M and Q, the data was sorted into four (4) categories.

1. Well-Bonded – good signal quality indicated by the green circles in Figure 15 and Figure 16
2. Partial Bonding – (cracking/poor grout) – fair signal quality indicated by orange circles
3. Poor/No Bonding – (cracking/poor grout) – poor signal quality indicated by red circles
4. Poor/No Bonding – (cracking/poor grout high potential for delamination/ voiding) – poor signal quality indicated by red circles with squares

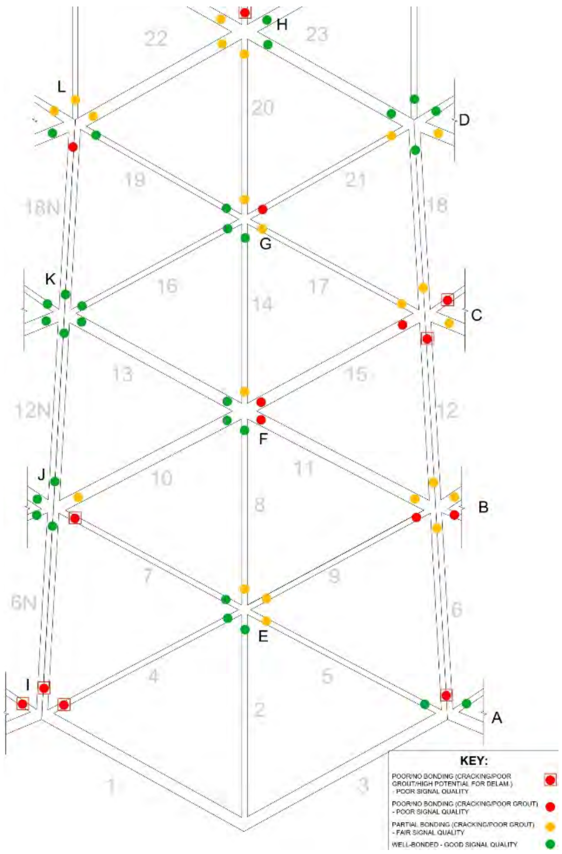


Figure 15: Weld Plate Testing of Element M

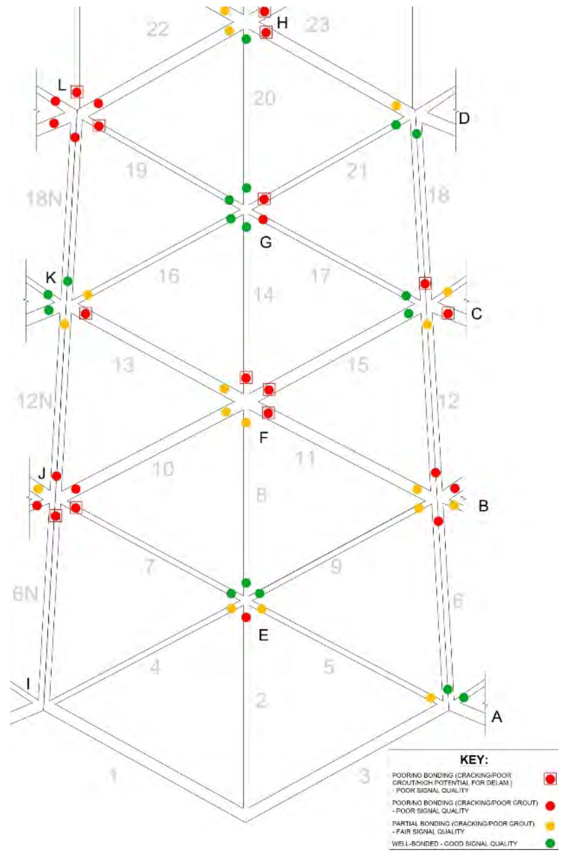
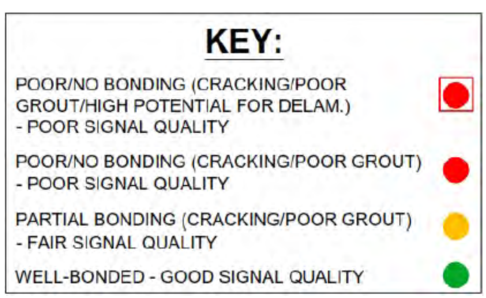


Figure 16: Weld Plate Testing of Element Q



A summary of these test results in presented in Table 7.

Table 7: Weld Plate Testing Results

Category	Element M	Element Q	Combined
Well-bonded	29 (44%)	17 (29%)	46 (36.8%)
Partially bonded	22 (33%)	17 (29%)	39 (31.2%)
Poor/ No bonding	7 (11%)	12 (20%)	19 (15.2%)
Poor/No bond – potential void	8 (12%)	13 (22%)	21 (16.8%)

Element Mid-Point Weld Plates

Sonic/ultrasonic measurements for element plates were conducted in a through member configuration. A single measurement was conducted at each member with the energy source positioned opposite the middle sensor of a 3 sensor array (sensors spaced 6 inches) approximately 1-2 inch from the glazing anchor point as shown in Figure 14. These measurements provide a general assessment of the internal condition of the integrally cast weld plates.

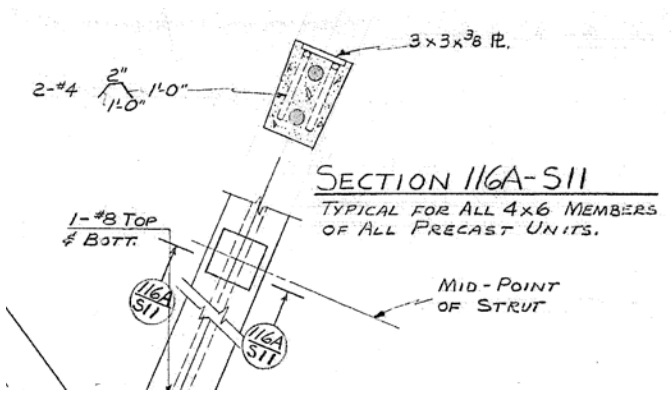


Figure 17: Mid-Point Weld Plate Detail

The data was classified based in signal quality using the same four categories as used for the connection weld plates. The results are presented in Figure 18 and Figure 19.

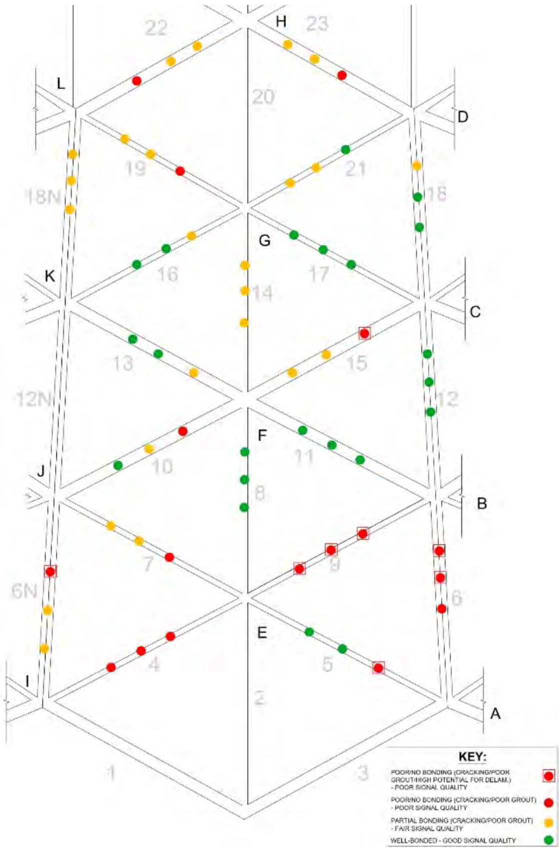


Figure 18: Element Plate Testing of Element M

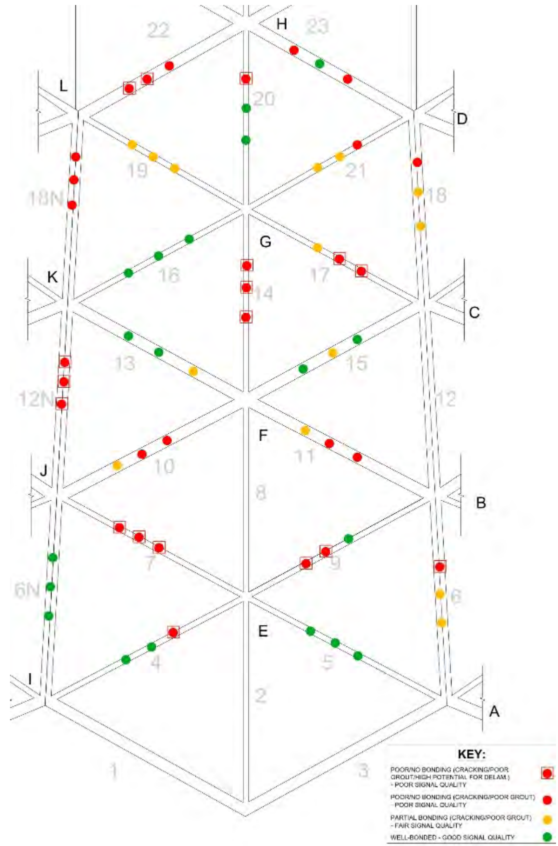


Figure 19: Element Plate Testing of Element Q

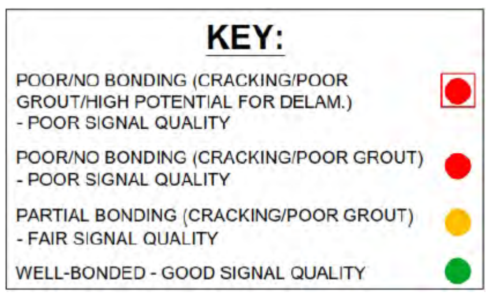


Table 8 presents a summary of the assessed quality of contact between the cast-in weld plates to the concrete at the center of each member.

Table 8: Intermediate Weld Plate Testing Results

Category	Segment M	Segment Q	Combined
Well-bonded	25 (38%)	22 (34%)	47 (35.6%)
Partially bonded	24 (36%)	14 (21%)	38 (28.8%)
Poor/ No bonding	9 (14%)	12 (18%)	21 (15.9%)
Poor/No bond - void?	8 (12%)	18 (27%)	26 (19.7%)

Table 8 indicates similar quantities as Table 7 for the quality of contact between the weld plates and the concrete. However, the “poor bond” finding is more likely the result of a small air gap between the weld plate and the concrete than any other phenomenon. These weld plates were cast into the concrete, so it is plausible that the process of welding and thermal movements of the glazing may have influenced or loosened the plates slightly. Visual observations indicate the weld plates are intact and in good shape. If a small air gap was present when it was originally cast, the air gap would register as a potential void in this test arrangement.

Vertical Grout Pockets

Sonic/ultrasonic though measurements were conducted with the energy source (high frequency energy source) located on one face of the structure and a single sensor located at the same location on the opposing face of the element. These measurements provide a general assessment of the internal condition of the grout pocket/shear key formed where sectors join.

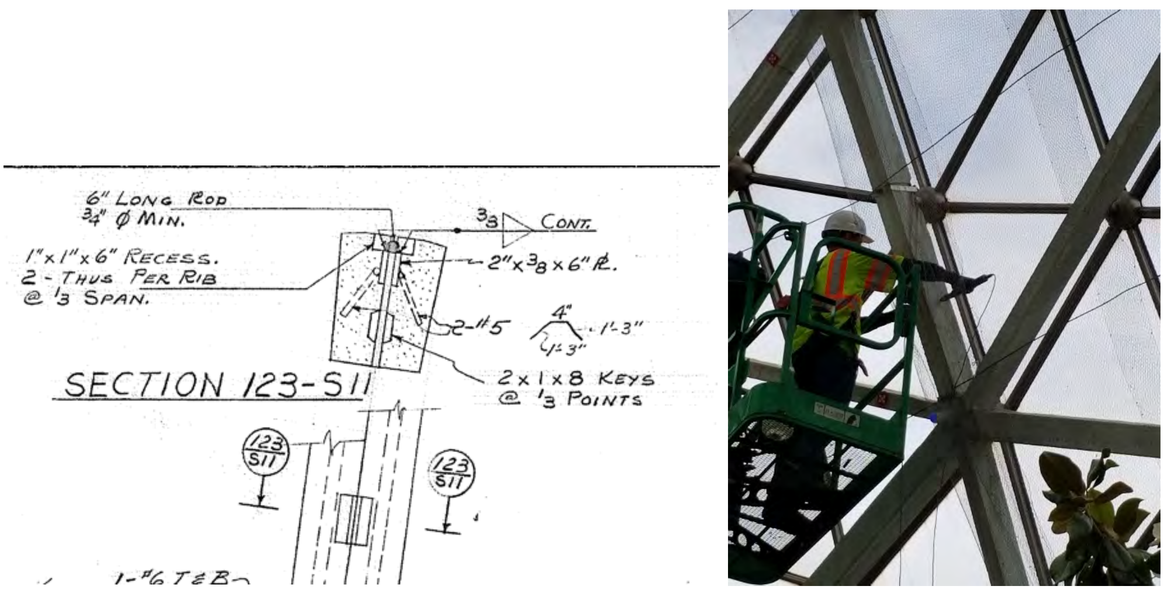


Figure 20: Vertical Sector-to-Sector Connection Detail and Test Arrangement

Measurements were performed at eight locations in each Area M and Q, with a total of 16 tested locations. The same four categories as described previously were used to categorize the measurements based on signal quality. It was determined that 11 measurements (69%) in both elements indicated that the grout pockets were well-bonded and 5 measurements (31%) indicated partial bonding of the grout pockets. These results are illustrated in Figure 21 and Figure 22. It is important to note that no vertical grout joints were categorized as voided.

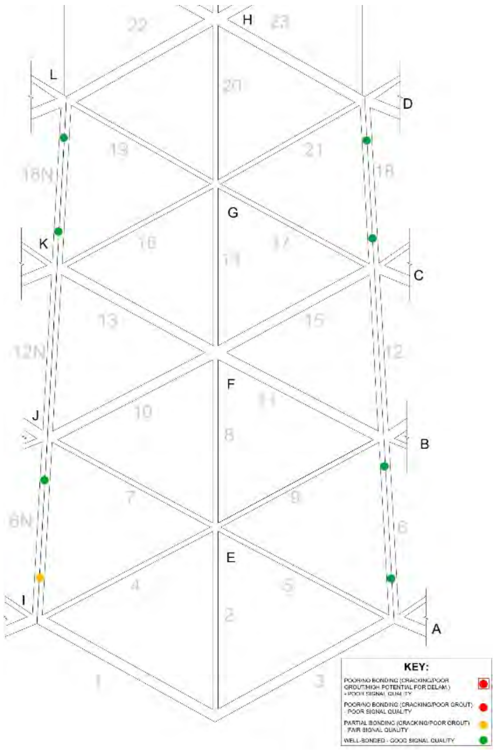


Figure 21: Vertical Grout Pockets Testing of Element M

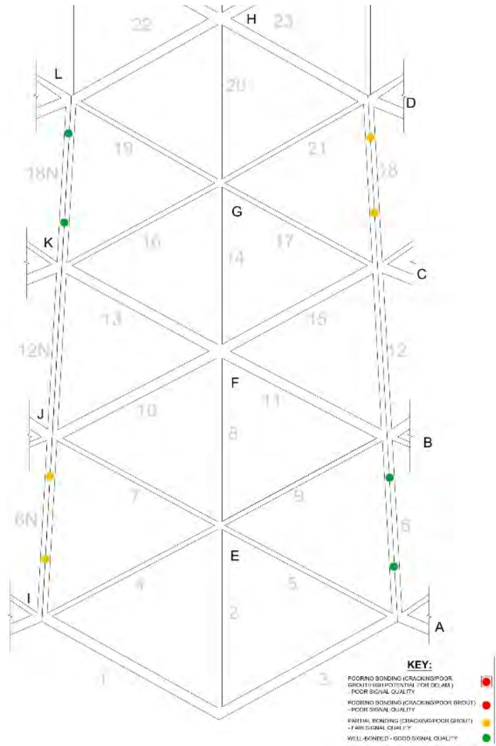
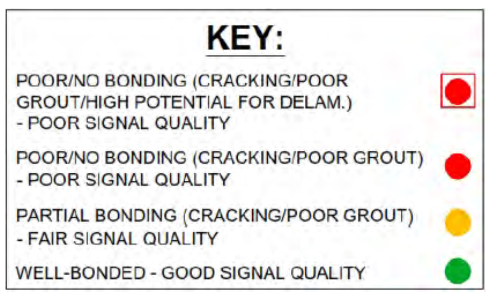


Figure 22: Vertical Grout Pockets Testing of Element Q



Concrete Material Sampling

In addition to non-destructive methods, concrete material sampling was conducted to gain an understanding of the ingress of carbonation and the amount of chloride ion contamination within the concrete matrix.

Concrete Chloride Sampling

Reinforcing steel in concrete is protected from corrosion by the high alkalinity of the concrete pore solution, typically greater than a pH of 12. The high pH of the pore solution causes formation of a passivating oxide film on the surface of rebar, effectively sealing it and preventing corrosion. Corrosion of reinforced concrete exposed to deicing salt chemicals is typically initiated by chloride ions, which have the ability to break down the passivating film. Chloride ions diffuse from the concrete surface, and once their concentration at reinforcement depth reaches a threshold value, corrosion is initiated. The generally accepted chloride threshold for the initiation of corrosion at the depth of steel in reinforced concrete is 350 ppm. Concrete can also contain background chlorides, which were either admixed into fresh concrete or are naturally present in the aggregates, the mix water, or cementitious products.

Admixed chlorides could be present in the concrete as a result of using chloride-containing chemical admixtures, or the use of seawater instead of potable water. Admixed chlorides and chloride ions that diffuse into the concrete from the environment are referred to as “free” chlorides and are responsible for chloride-induced corrosion in reinforced concrete. Chlorides present in the aggregate are chemically bound and are not able to initiate corrosion.

Concrete samples were collected from the structure to evaluate the level of chloride contamination and the risk for corrosion activity of the steel reinforcing per ASTM C1152 *Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete*, which measures the concentration of both free and bound chlorides. The concrete samples were collected in the form of powder samples obtained by drilling into the concrete beams in 0.5-inch depth increments. The results of the chloride testing are presented in Table 9.

Table 9: Chloride Concentration in Precast Concrete Beams

	Chloride Concentration (ppm)	
Sample Location	**Depth 0-0.5 in**	**Depth 0.5-1 in**
Q10	385	422
Q15	417	409
M7	380	498

Generally, the amount of bound chlorides in a concrete mix is low, below 100 ppm, and determination of acid-soluble chlorides is typically sufficient to evaluate corrosion risk. However, dolomitic limestone and other aggregates commonly found in the Great Lakes Region are known to have high concentrations of background chlorides. Although the chloride concentration in the beams was above the typical corrosion initiation threshold, no significant decrease in chloride concentration was observed with increasing depth, and no wide-spread corrosion deterioration was observed. This indicates that the high chloride concentration is likely due to bound chlorides present in the aggregate.

Carbonation Depth

The depth of carbonation into the concrete can indicate the risk for corrosion activity. Carbonation lowers the concrete’s pH as carbon dioxide diffuses into moist concrete. If the pH of the concrete surrounding the reinforcing steel is lowered below pH 11, depassivation of the reinforcing begins and general corrosion initiates. Carbonation can cause corrosion in concrete that has not been contaminated with chlorides and can also propagate along cracked surfaces. In chloride-contaminated concrete, carbonation can work in tandem with chlorides to initiate corrosion much more quickly.

To identify the depth of the carbonation front in concrete, 16 holes were drilled in elements M and Q and sprayed with a phenolphthalein indicator solution to indicate pH. The indicator solution changes to a pink/purple color at pH greater than 9.5. If the concrete is not colored purple or pink, the concrete has a pH less than 9.5. This indicates the depth of carbonated concrete; if the solution turns purple or pink on the concrete then that is an indication of uncarbonated or alkaline concrete. The measured depth of carbonation ranged from 0 to 0.25 inches, with an average carbonation depth of 0.09 inches. Considering the average reinforcement cover-depth of the concrete beams was determined to be 0.9 inches, there is little to no risk of corrosion due to carbonation.

Figure 23: Carbonation Depth Testing

Joint F Openings

Two openings were made to expose the weld plates at Joint F in both test areas. This joint is a “hub” location where several beam elements combine at one hexagonal weld plate, as shown in Figure 10. These weld plates are located on the glass-side of the concrete frame, with a hemi-spherically shaped glazing frame connection hub welded to it. The distance between the glass and the concrete frame is less than eight inches. Concrete removal in both locations was limited to the top half of the weld plate to expose the exterior reinforcing of vertical member No. 14 that is welded to the plate.

Joint F was selected because the corrosion gradient analysis indicated that it was likely for corrosion activity to be present. We made the opening by drilling several holes into the concrete joint, then using a small chipping hammer to remove the cover concrete. While doing so we noticed a crack developed in the paint that outlined a square block-out. We placed the chipping hammer on the crack and removed the poorly consolidated grout sample shown in Figure 24. Additional images are provided in Figure 25.

Figure 24: Area M Joint F and Grout Chunk

Figure 25: Opening of Weld Plate F in Area M.

The top left photo in Figure 25 shows the overall corrosion activity is very superficial. Rust stains on the concrete grout chunk indicate that the corrosion activity occurred in situ. It was not “pre-rusted”. The weld plates also show some minor localized corrosion of the rebar, along the edges, and near the weld for the horizontal beam framing into it. All these areas can be considered as general surface corrosion caused by moisture in grout voids. There was no apparent section loss to either plate.

The top right photo shows the void we found behind the weld plate and if you zoom in on the reinforcing there are some grinder marks from the welding preparation that appear to have rusted and resulted in some section loss. The bottom photo provides the blockout dimension.

Figure 26: Opening of Weld Plate F in Area Q

The weld Plate in Area Q was similar, but had significantly less visible corrosion activity. Note the clean, smooth back surface of the blockout in the right photo. This smooth concrete surface made grout removal relatively easy. It appears that the grout was probably “dry-packed” and may never have bonded to this surface. This weld plate had a much thinner gap behind the plate, approx. ¼ inch, but it also had a little corrosion activity and grinder marks on the reinforcing just above the weld plate. The overall condition of the weld plate was excellent, with shear marks still present. The outer weld plate, where the glazing hub is welded had corrosion along the top edge, as seen in the left photo, where it was exposed to moisture infiltration. No section loss occurred. All corrosion observed can be considered general surface corrosion.

Interpretation of Results

Summary of Findings

1. GPR survey indicates that concrete cover ranged from 0.1 to 2.3 inches with a mean of 0.9 inches and standard deviation of 0.6 inches.
2. The reinforcing steel was found to be electrically continuous.
3. Corrosion potentials indicate the reinforcing is generally passive, due to the mostly dry concrete frame. However, potential gradient analysis indicate that corrosion is likely at the weld plates.
4. Concrete strength estimates obtained from the sonic survey indicate good compressive strength. Using the relationship for calculating design strength from the mean and standard deviation of test results contained in the ACI building code, the approximate design strength, $f_c' = f_{cr} - 1.34\,S$ is for:
   a. beams - 4,000 psi.
   b. foundation – 6,400 psi
5. Wave analysis across the shear keys at intersections generally shows poor or partial bonding. This means that it is likely the grout in the shear keys is honeycombed, poorly bonded, or does not completely fill the shear keys.
6. Wave analysis of the weld plate tests indicates roughly 1/3 are fully bonded, 1/3 are partially bonded, and 1/3 are poorly bonded or voided. Figure 13 and Figure 14 illustrate that 1 out of 23 weld plates was fully bonded at all sides, 2 out of 23 were entirely poor and that 20 of the 23 the weld plates were a mixed bag with combinations of good, partial, and poor signal transmission though the weld plates

at different locations. This leads to the conclusion that the original grout has either deteriorated or was never completely consolidated.

7. Intermediate weld plates had similar proportions of good and poor bonding that element connection weld plates had. However, these weld plates were cast in place. Visual observation of the weld plates indicates that they are sound and in good condition. These weld plates are not defective. The sonic data indicates that about 1/3 may have an air gap between the concrete and plate.
8. Vertical grout joints between double members were found to be in good condition.
9. Chloride content of the concrete appeared to be elevated, but there was no external gradient, so chloride was either admixed or bound in the aggregates.
10. Carbonation was minimal with a mean carbonation depth less than 0.1 inch.
11. Openings confirmed mild corrosion activity occurring at weld plates that were either exposed to external moisture, not completely grouted, or where the grout was not fully consolidated.

Discussion

Overall, the findings indicate that the SHOW DOME concrete frame is in reasonably good condition. Concrete members are sound, it has good design strength, and is not showing signs of progressive deterioration from any of the common distress mechanisms (corrosion, reactive aggregate, freeze-thaw, chemical attack). The problems identified stem from initial design and construction. So, if the representative areas tested are actually representative of the overall conditions, the SHOW DOME concrete frame can last several more decades if a few maintenance interventions are included in any future glazing replacement effort. There really is no deterioration mechanism other than the very mild corrosion found that should shorten the life of the SHOW DOME.

Recommended concrete frame maintenance activities to include with glazing replacement:

1. Evaluation of members: (similar to openings at joint F). The idea here is to identify the areas where intervention is warranted. If this step is not included, do step 2 at 100% of joints.
    a. Verify soundness of grout behind weld plates using sonic through-member testing identified in Figure 14 through Figure 16.
    b. Conduct a corrosion potential survey to locate joints with corrosion activity.
2. Remove grout, clean, and repack grout in unsound areas, and/or joints with corrosion activity (this could be roughly 1/3 of the 350 total panel to panel weld joints. (14 per sector, 25 sectors = 350: see joints identified on original drawing S-11 as A through H plus 6 vertical panel to panel joints per sector)
    a. Consider adding small grouted-in galvanic anodes at corroding areas.
    b. Consider paint removal and treating all joints with a penetrating low-viscosity primer (MMA or Epoxy based) and epoxy-urethane coating to prevent moisture penetration into grout pockets.
3. Remove all thin concrete edges at all weld plates, clean and coat the edges of weld plates with a zinc-rich primer, followed by a low-viscosity primer and epoxy-urethane coating after any new welding operations.
4. Paint: clean or strip and recoat throughout. (Any top coating will need to be compatible with the existing.)

The rationale for these recommended activities is that we found no serious deterioration mechanisms in play, but we did find defects associated with initial construction quality control that could become problematic if left unattended.

At this time in the SHOW DOME, the observed corrosion activity at the two openings was superficial. We do not know if these observations are representative of the overall population of weld plates, but we believe it is. In a situation where there is a large quantity of repeating construction details, a range of conditions will exist in the total population. The population will have some elements in better and in worse condition, so it is prudent to take advantage of the opportunity to identify and correct the deficiency when the opportunity presents itself.

The opportunity to address these conditions efficiently is when the glazing is removed, and scaffolding is in place.

Description of grout pocket deterioration mechanism

The limited corrosion activity identified in the show dome is associated with poorly consolidated grout at blockouts formed for panel to panel connection weld plates. When it rains, water leaking through the failed glazing flows along the members and enters small cracks at the perimeter of grout pockets and finds its way to the reinforcing. The moisture will leech some ions from the concrete that will reduce the local pH along the crack. Over time, neutral or low pH moisture contacts the weld plates or reinforcing at the voids, and general surface corrosion begins.

The areas with intimate grout contact are not at risk, it is the voids that cause problems. When moisture contacts bare steel in a void, general surface corrosion similar to atmospheric corrosion begins. If the corrosion activity is supported by the local environment, it will continue inside the void. In wet environments, section loss could become significant. However, in the SHOW DOME it is mostly dry so most of the moisture that enters cracks at the perimeter of the grouted block outs is likely absorbed by the dry concrete. It is only when enough moisture enters the cracks that corrosion occurs. So, the corrosion activity is limited and periodic in the SHOW DOME.

Carbonation

The wide range of concrete cover found in the SHOW DOME is most likely representative of all three domes. Carbonation progresses inward when concrete goes through wet-dry cycles. When it dries, carbon dioxide in the air reacts with the moisture at the drying front to create bicarbonate and carbonic acid, which is buffered/neutralized by free hydroxide ion. The result is a precipitate of calcium carbonate with neutral pH. Over time, this reduced pH front progresses inward until it contacts reinforcing. The reinforcing corrodes when the pH falls below 11, so low cover reinforcing in porous concrete subject to wet-dry cycles is at risk for carbonation.

The first line of defense against carbonation is to block carbon dioxide and moisture from the concrete using a quality barrier coating. A barrier has been applied to the concrete frame of all three domes, but some of the bars are so close to the surface that corrosion has already initiated. In those cases, repair of the spalls and installation of a small galvanic anode to prevent further corrosion is warranted.

Application of Findings to Other Domes

Arid Dome:

The ARID DOME is functionally similar to the SHOW DOME from the concrete's perspective. When it rains, water leaks through the glazing and flows along the concrete frame until it drips off or finds its way into a crack. Maintenance recommendations and estimated quantities for the ARID and SHOW domes should be similar. The environment in the ARID dome is drier, so the potential for deeper carbonation is greater. We expect slightly deeper carbonation in the ARID dome, but the overall conditions are the same as the SHOW DOME so maintenance recommendations should not differ.

Tropical Dome:
The TROPICAL DOME has a very moist environment, so corrosion distress will have advanced further in this dome if the construction quality is similar to what we found in the SHOW DOME. If there are limited funds, the county should consider replacement of the TROPICAL DOME glazing first. We walked through the TROPICAL DOME during our time on site and identified numerous locations where low-cover concrete had spalled, presumably from corrosion. These areas were coated with what appeared to be a zinc-rich primer. This primer is a good stop-gap measure to minimize staining. However, the primer is not durable long-term.

Concrete patch repairs are needed. Small galvanic anodes that can be drilled and grouted between the reinforcing bars to protect low cover areas. Galvanic anodes should be coupled with repairs inside this dome, primarily because the members are so slender that adding concrete cover would become an eyesore. Galvanic cathodic protection is the only thing that has been proven to stop corrosion after it has initiated.

The coating on the TROPICAL DOME concrete frame has failed. Large areas of peeling and flaking coating are present everywhere and algae is growing on most of it. Removal and replacement of the coating in the TROPICAL DOME is necessary for aesthetics and to protect the concrete.

Weld plates in the TROPICAL DOME are exposed to constant moisture. It is likely that there is more significant corrosion on the surface plates than the internal grouted element connection plates. In this environment, the surface plates are likely to have the most corrosion distress. The same maintenance activities should apply, but there may be some situations where corrosion has initiated under the plate and section loss of the plate or anchor weld may have occurred. If so, structural assessment and a surface plate repair detail is needed. If plate replacement is needed, it can be determined easily once the existing glazing is removed and scaffolding is in place. Please understand that we have no proof of any significant durability issues with these plates. We are simply cautioning that the environment of the TROPICAL DOME is more conducive to corrosion distress, so the potential exists for more significant distress than what was found in the SHOW DOME.

APPENDIX A

Background Information for Ultrasound Measurements on Concrete

CRC Handbook on Nondestructive Testing of Concrete

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This test method may be used to advantage to assess the uniformity and relative quality of concrete, to indicate the presence of voids and cracks, to estimate the depth of cracks, to indicate changes in the properties of concrete, and in the survey of structures, to estimate the severity of deterioration or cracking.

The results obtained by the use of this test method should not be considered as a means of measuring strength nor as an adequate test for establishing compliance of the modulus of elasticity of field concrete with that assumed in design.

The procedure is applicable in both field and laboratory testing regardless of size or shape of the specimen within the limitations of available pulse-generating sources.

APPLICATIONS

The pulse velocity method has been used successfully in laboratory as well as in the field.[28-48] Furthermore, it can be used for quality control and quality assurance, as well as for the analysis of deterioration.

DETERMINATION OF DYNAMIC MODULUS OF ELASTICITY AND POISSON'S RATIO

One of the most direct uses, and theoretically the most correct use of the pulse velocity method, is in determining dynamic modulus of elasticity and Poisson's ratio of concrete. Using Equation 1, Leslie and Cheesman,[5] Whitehurst,[7] Philleo,[28] Goodell,[29] and Swamy[30] have published detailed test results. The dynamic Poisson's ratio of concrete can be assumed to be between 0.2 to 0.3 for most concretes. This assumed value will lead to an error of about 10%, or less, for the value of the dynamic modulus of elasticity.

ESTIMATION OF STRENGTH OF CONCRETE

The pulse velocity method provides a convenient means of estimating the strength of both *in situ* and precast concrete. The strength can be estimated from the pulse velocity by a pre-established graphical correlation between the two parameters, for example, as shown in Figure 6. The relationship between strength and pulse velocity is not unique, but is affected by many factors, e.g., aggregate size, type and content, cement type and content, water-to-cement ratio, moisture content, etc. The effect of such factors has been studied by many researchers.[10,16,18,20,21] They have clearly pointed out that no attempts should be made to estimate compressive strength of concrete from pulse velocity values unless similar correlations have been previously established for the type of concrete under investigation. RILEM[23] and British Standard[24] have provided recommended practices to develop the pre-established relationship between pulse velocity and compressive strength, which can be later used for estimating the *in situ* strength based upon the pulse velocity.

ESTABLISHING HOMOGENEITY OF CONCRETE

The pulse velocity method is very suitable for the study of homogeneity of concrete, and therefore for relative assessment of quality of concrete. Heterogeneities in a concrete member will cause variations in the pulse velocity. *In situ* concrete strength varies in a structure because of the variations in materials, supply and in mixing, and due to inadequate or variable compaction. The pulse velocity method is extremely effective in establishing comparative data and for qualitative evaluation of concrete. For obtaining these qualitative data, a system of measuring points, i.e., a grid pattern, may be established. Depending upon the quantity of the concrete to be evaluated, the size of the structure, the variability expected, and the accuracy required, a grid of 6-in. (300-mm) spacing, or greater, should be established. Generally about 3-ft. (1-m) spacing is adequate. Other applications of this qualitative comparison of *in situ* or test specimen concrete are (1) to check the density of concrete in order to evaluate the effectiveness of consolidation, and (2) for locating areas of honeycombed concrete.

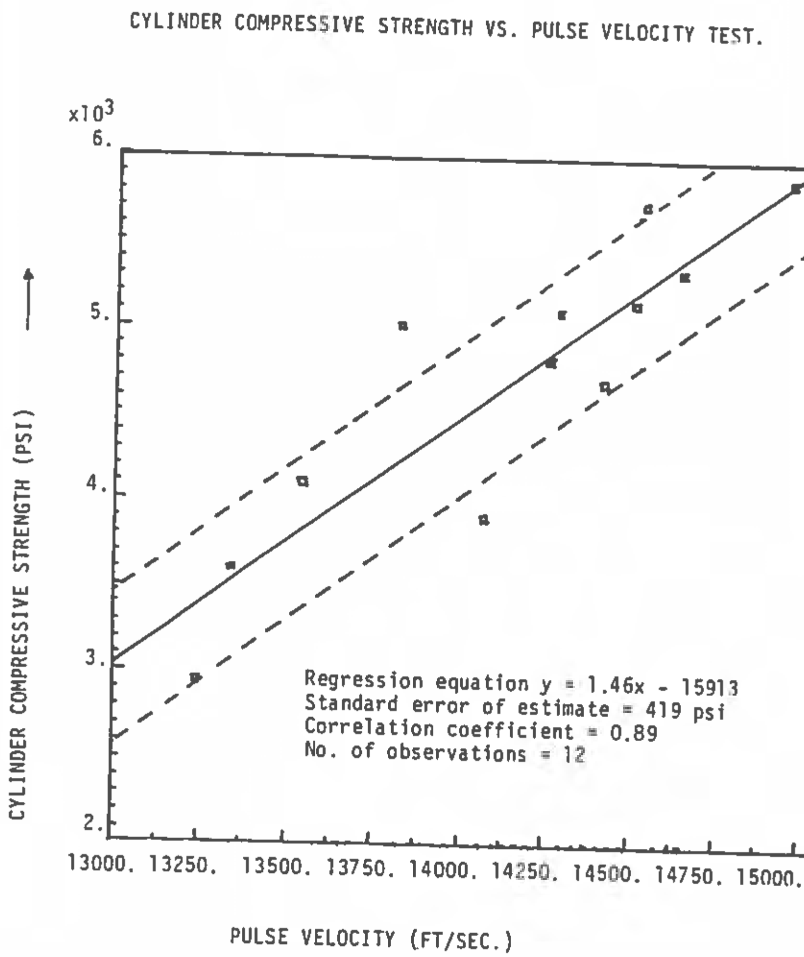


FIGURE 6. Velocity strength relationship for estimation of strength of concrete.

Many researchers[10,19,32-34,48] have reported results of carefully conducted surveys for determining the homogeneity of concrete in various types of structures. Of many such surveys carried out on existing structures, one that deserves mention is that reported in 1953 by Parker[32] of the Hydro-Electric Power Commission of Ontario, Canada. It was made on a dam built in 1914. A total of 50,000 readings were taken, most of them 1-ft (6.3-m) spacings. The pulse velocities measured on the structure ranged from below 5000 to over 17,000 ft/s (1525 to over 5185 m/s) and these values were used, with success, to determine the areas of advance deterioration. Recently, Naik[48] has reported a similar investigation on a dam built in 1906. Figure 7 shows field testing of mass concrete with the soniscope.[9] Some thousands of pulse velocity measurements have been made on 29 concrete dams during the period 1948—1965. McHenry and Oleson[35] cite ten of these case histories in which velocity measurements have been a valuable supplement to other observations in settling questions regarding repair or maintenance of dams.

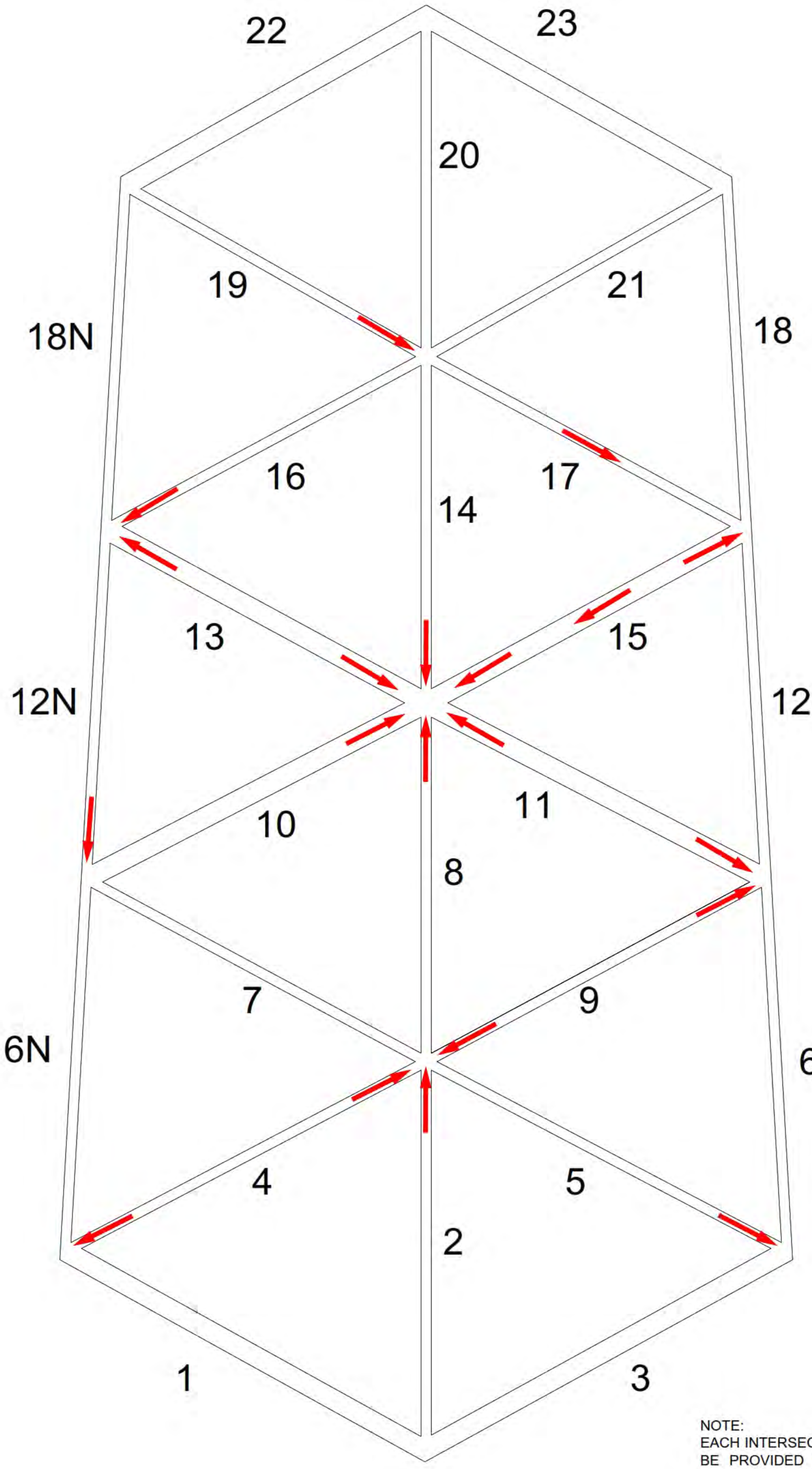
STUDIES ON THE HYDRATION OF CEMENT

The pulse velocity method has the advantage that it is truly nondestructive. Therefore, he changes in the internal structure of concrete can be monitored on the same test specimen.

Whitehurst,[7] Chefdeville,[36] Van de Winden and Brant,[37] and others have published nformation on successful application of the pulse velocity method for monitoring the hard-

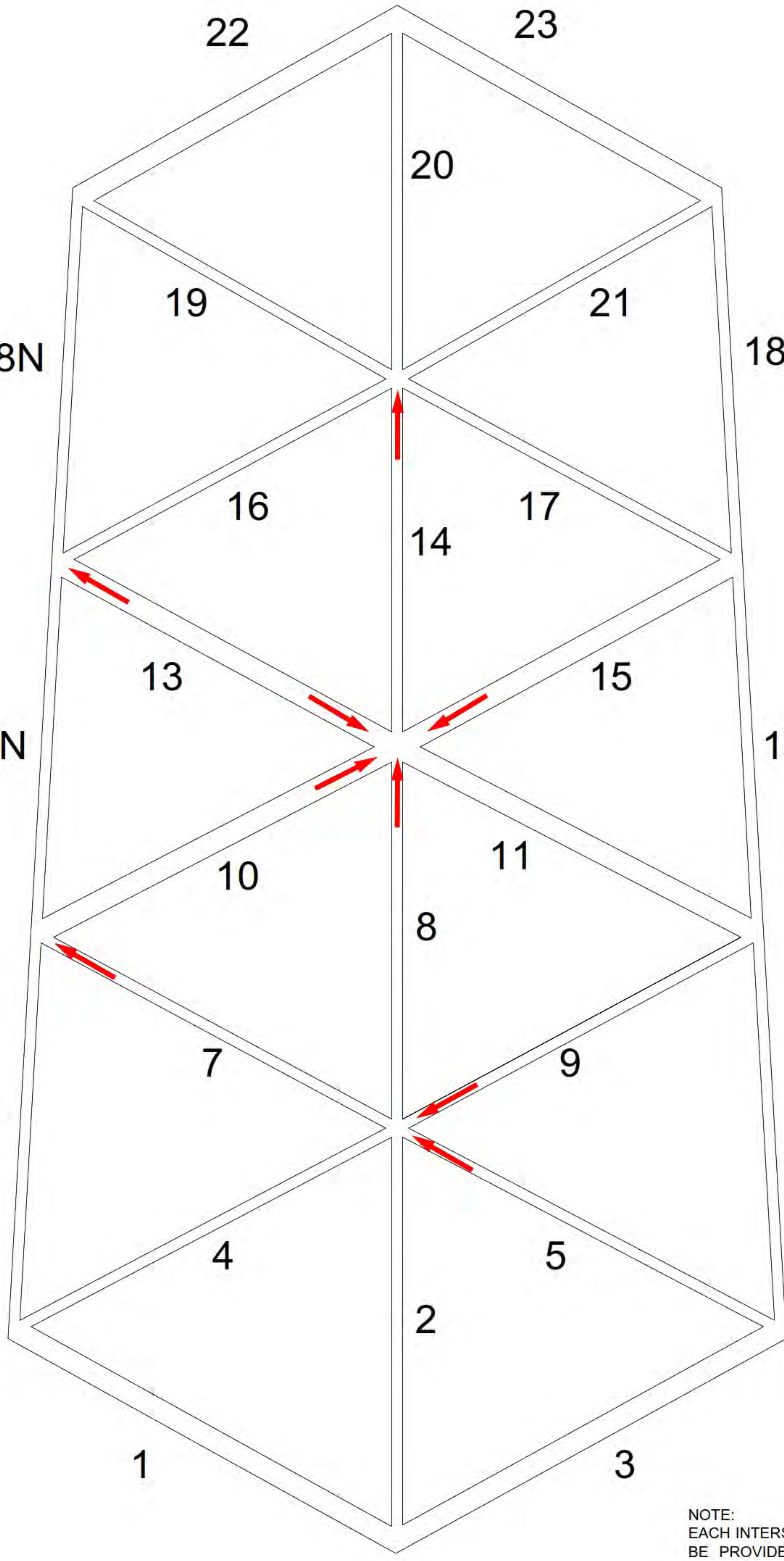
APPENDIX B

Test Plots



NOTE:
EACH INTERSECTION NODE WILL BE PROVIDED WITH A LETTER DESIGNATION BY NDT.

PROJECT NO. F19034WI DRAWING NO. 2	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	HALF-CELL DELTA OF DOME M	**MILWAUKEE DOMES** MILWAUKEE, WI	DRAWING REVISIONS # DATE BY DESCRIPTION 0



NOTE:
EACH INTERSECTION NODE WILL BE PROVIDED WITH A LETTER DESIGNATION BY NDT.

PROJECT NO. F19034WI DRAWING NO. 1	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	HALF-CELL DELTA OF DOME Q	**MILWAUKEE DOMES** MILWAUKEE, WI	VCS

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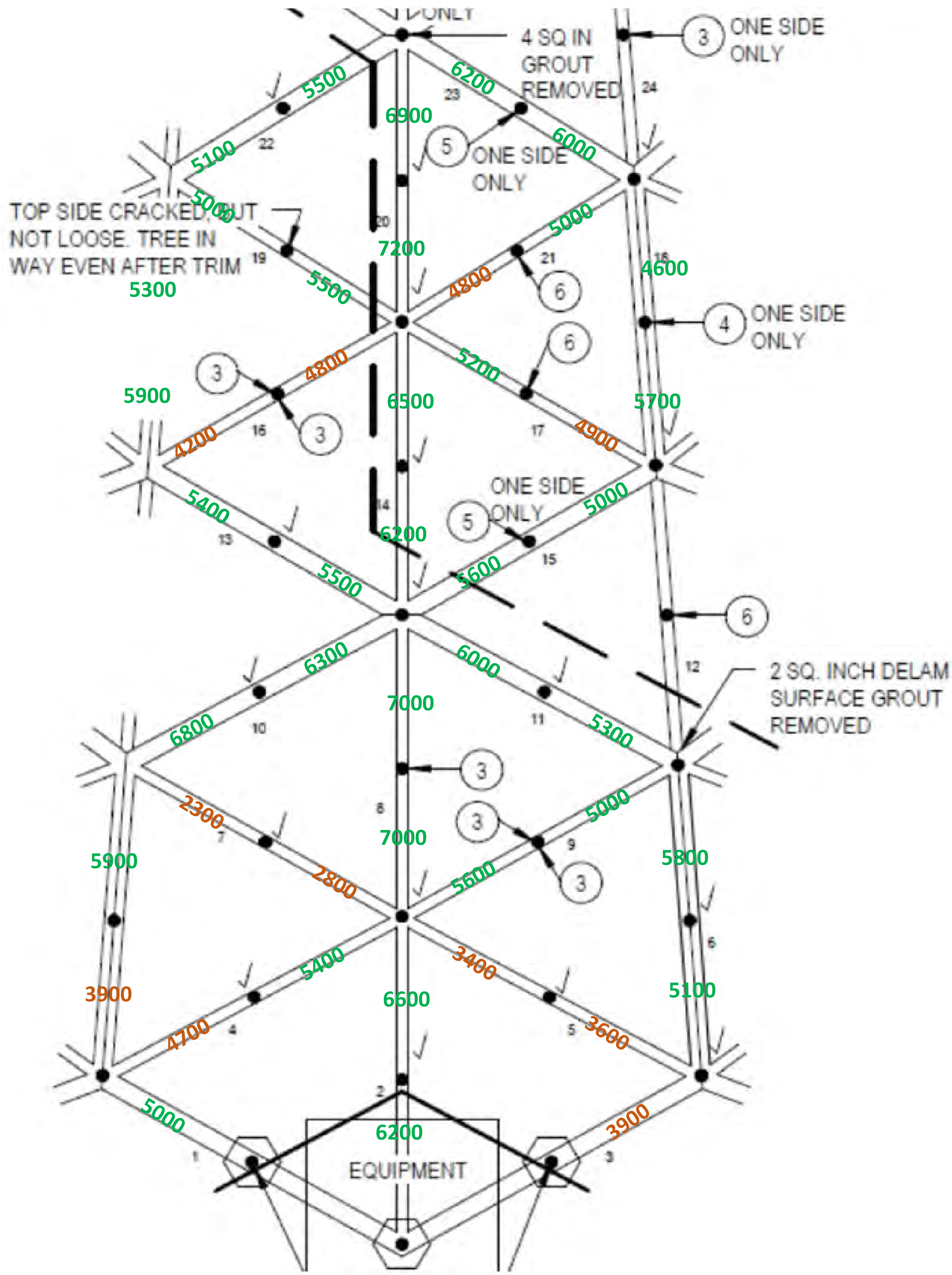
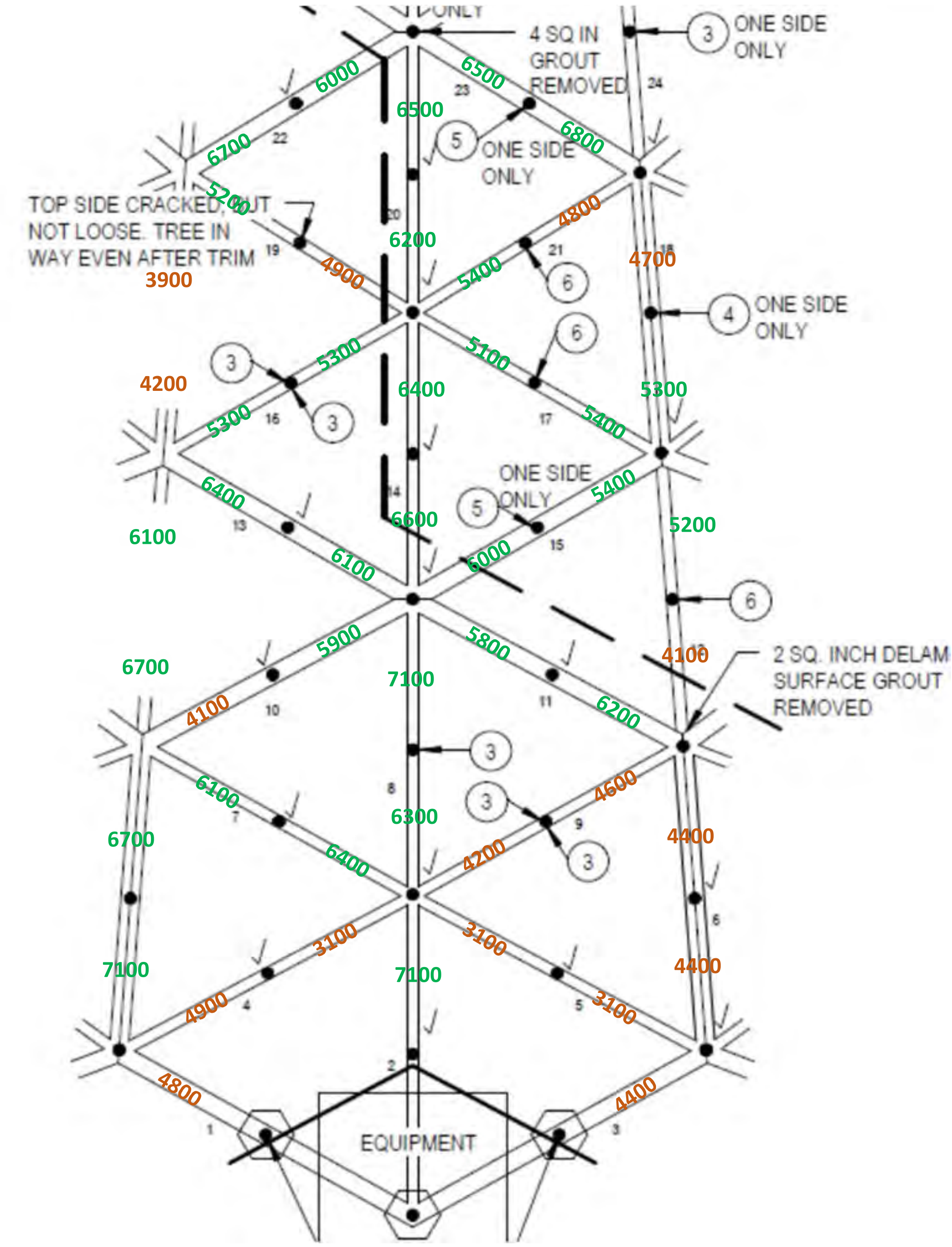
Sonic/ultrasonic velocity and strength results
Element M - Show Dome
Surface Measurements on Structural Units

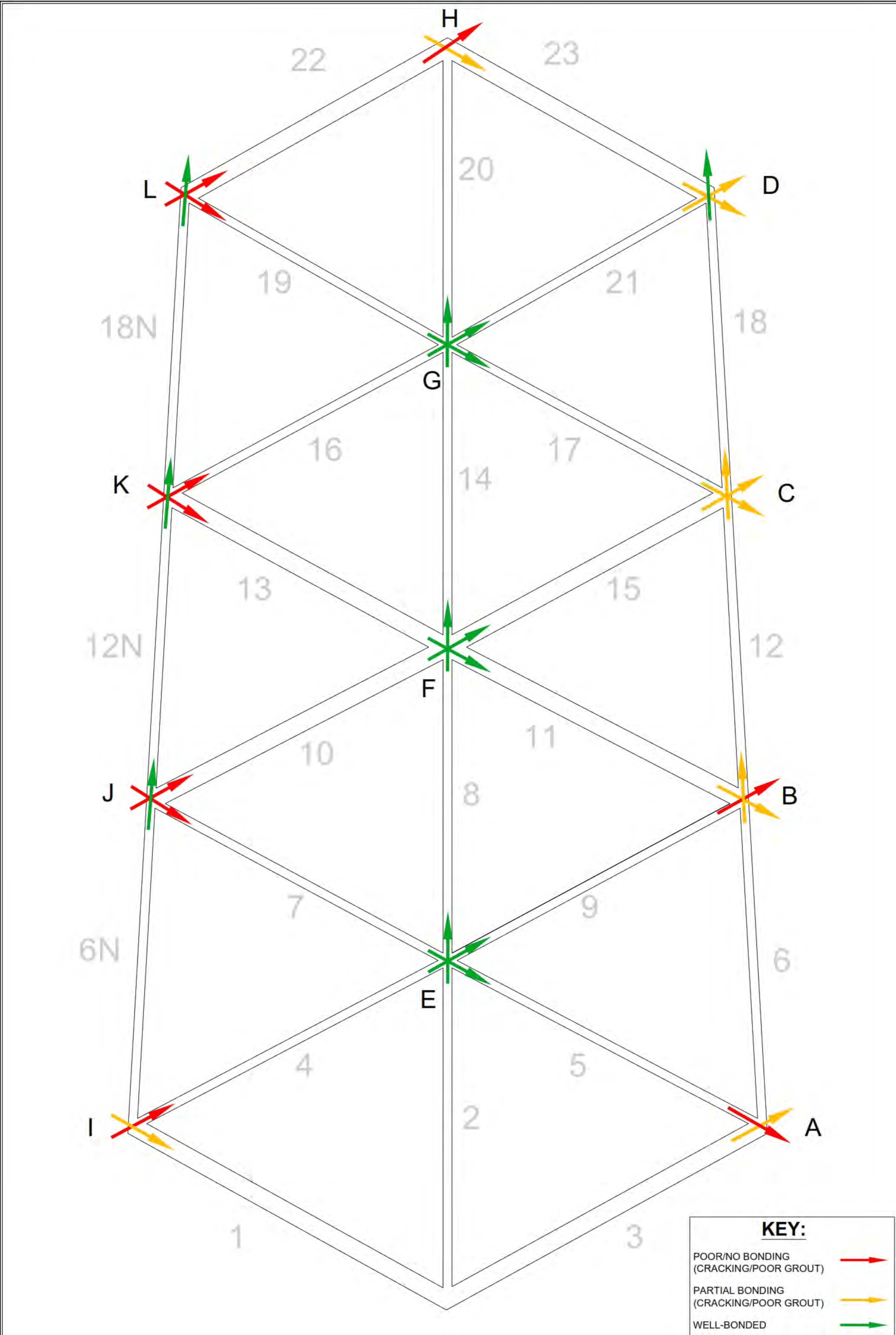


Compressional and Shear Wave values are directly measured and used to calculate an Average Calculated In-Situ Strength

Sonic/ultrasonic velocity and strength results
Element Q - Show Dome
Surface Measurements on Structural Units

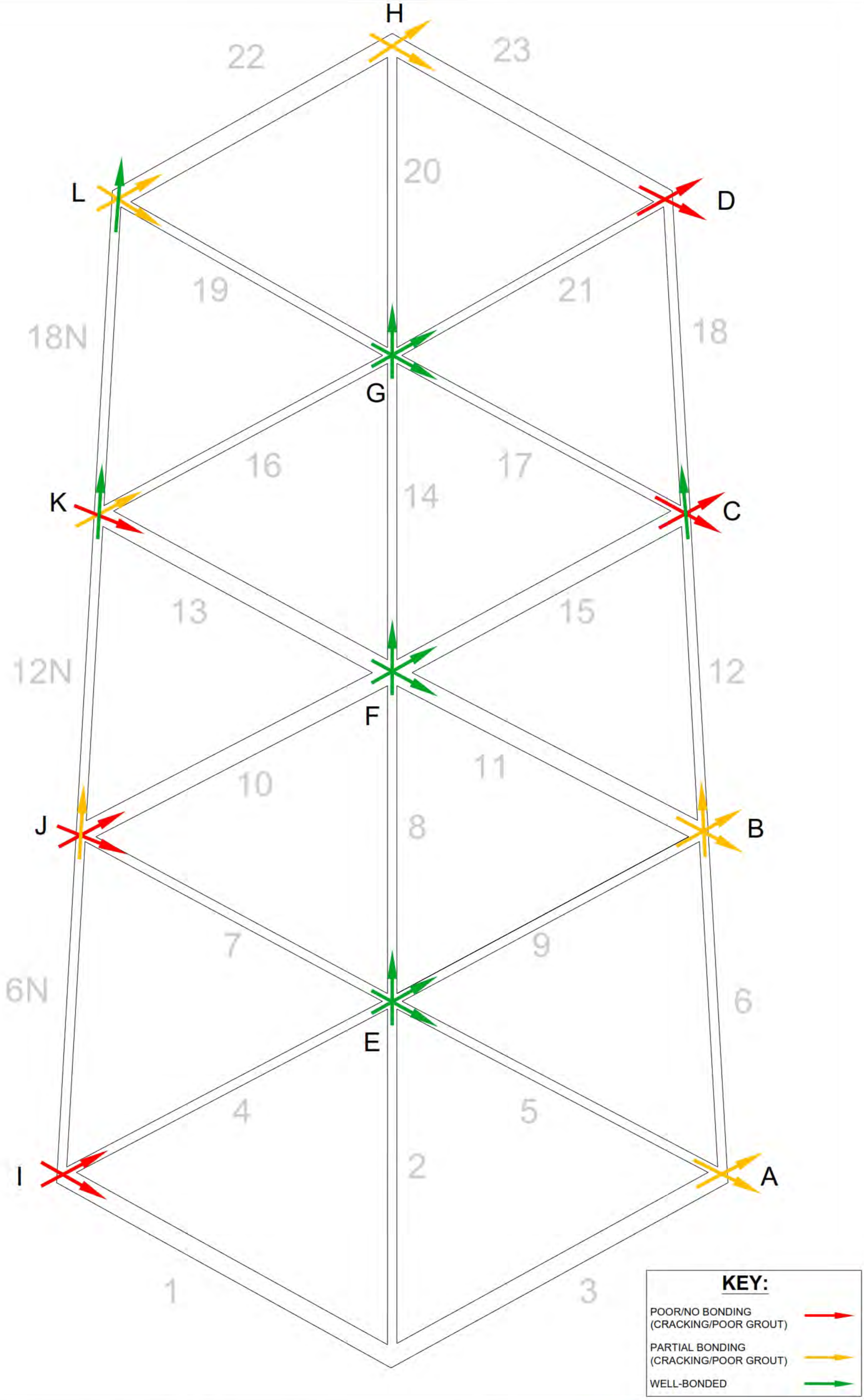


Compressional and Shear Wave values are directly measured and used to calculate an Average Calculated In-Situ Strength

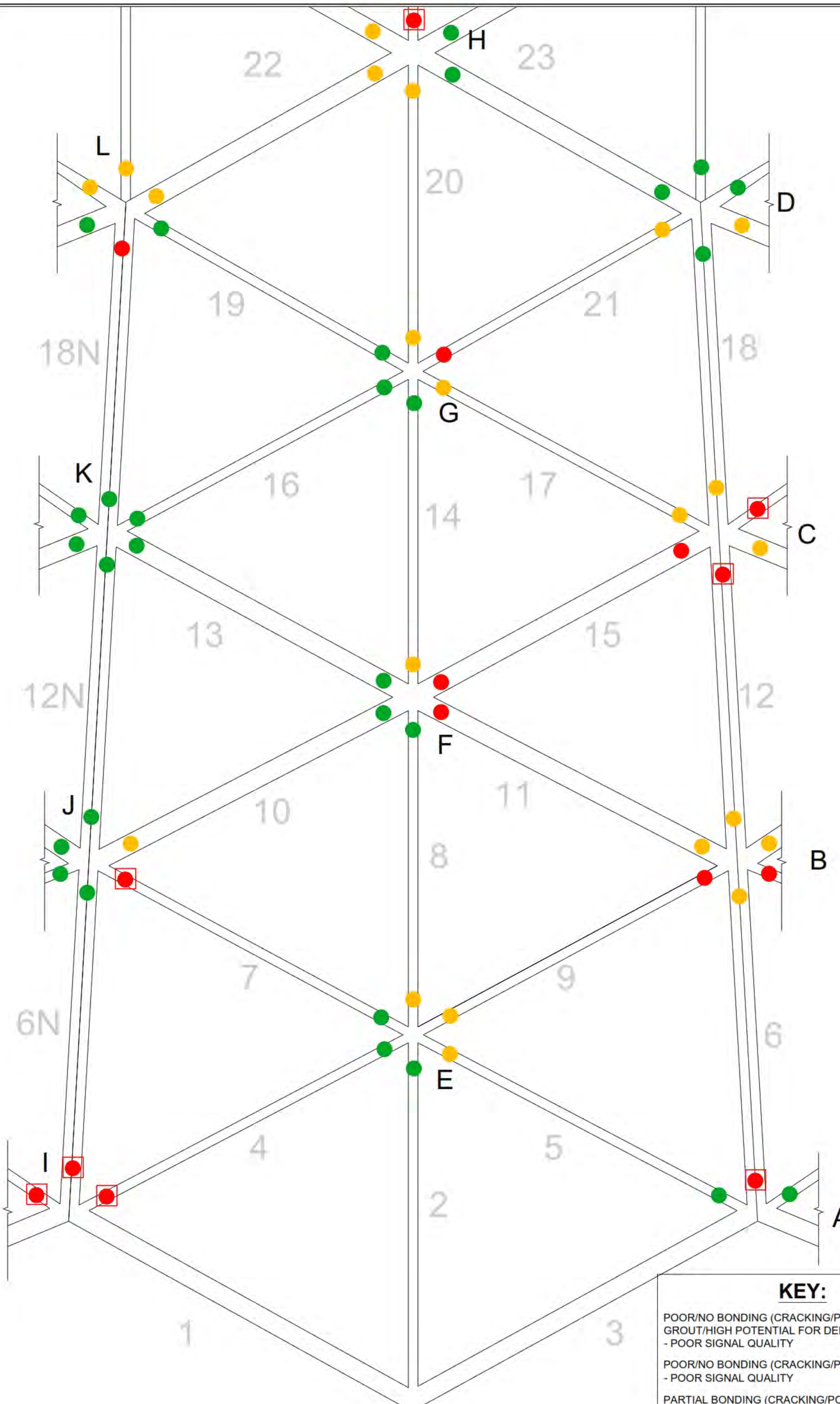


PROJECT NO. F19034WI DRAWING NO. 4	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	SHEAR KEY OF DOME M	**MILWAUKEE DOMES** MILWAUKEE, WI	DRAWING REVISIONS

#	DATE	BY	DESCRIPTION
0			



PROJECT NO. F19034WI DRAWING NO. 3	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	SHEAR KEY OF DOME Q	**MILWAUKEE DOMES** MILWAUKEE, WI	VCS	DRAWING REVISIONS # DATE BY DESCRIPTION



KEY:

POOR/NO BONDING (CRACKING/POOR GROUT/HIGH POTENTIAL FOR DELAM.) - POOR SIGNAL QUALITY

POOR/NO BONDING (CRACKING/POOR GROUT) - POOR SIGNAL QUALITY

PARTIAL BONDING (CRACKING/POOR GROUT) - FAIR SIGNAL QUALITY

WELL-BONDED - GOOD SIGNAL QUALITY

PROJECT NO. F19034WI DRAWING NO. 7	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	WELD PLATE OF DOME M	**MILWAUKEE DOMES** MILWAUKEE, WI	DRAWING REVISIONS

#	DATE	BY	DESCRIPTION
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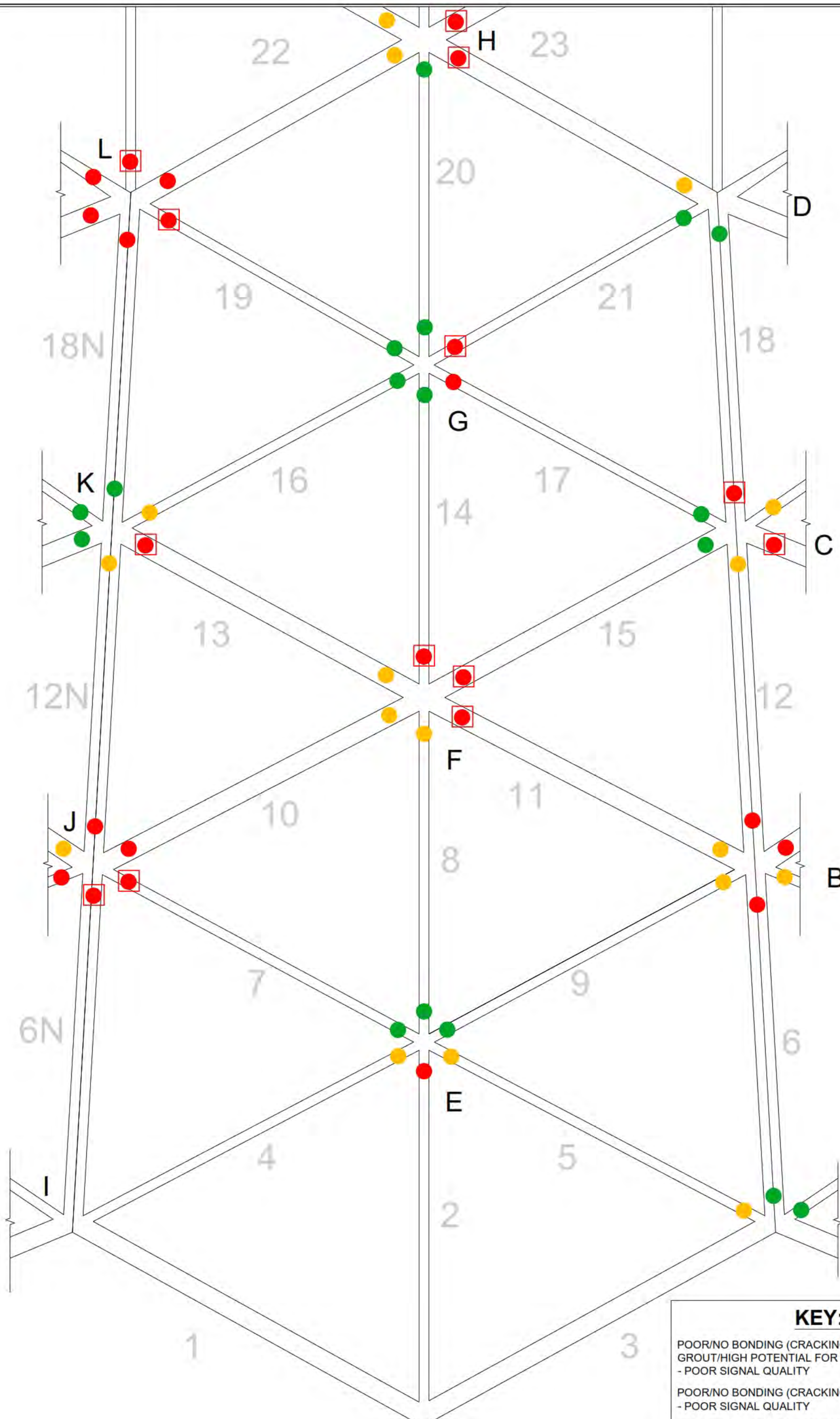

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- POOR/NO BONDING (CRACKING/POOR GROUT) - POOR SIGNAL QUALITY
- PARTIAL BONDING (CRACKING/POOR GROUT) - FAIR SIGNAL QUALITY
- WELL-BONDED - GOOD SIGNAL QUALITY

PROJECT NO. F19034WI DRAWING NO. 6	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	WELD PLATE OF DOME Q	**MILWAUKEE DOMES** MILWAUKEE, WI	VCS

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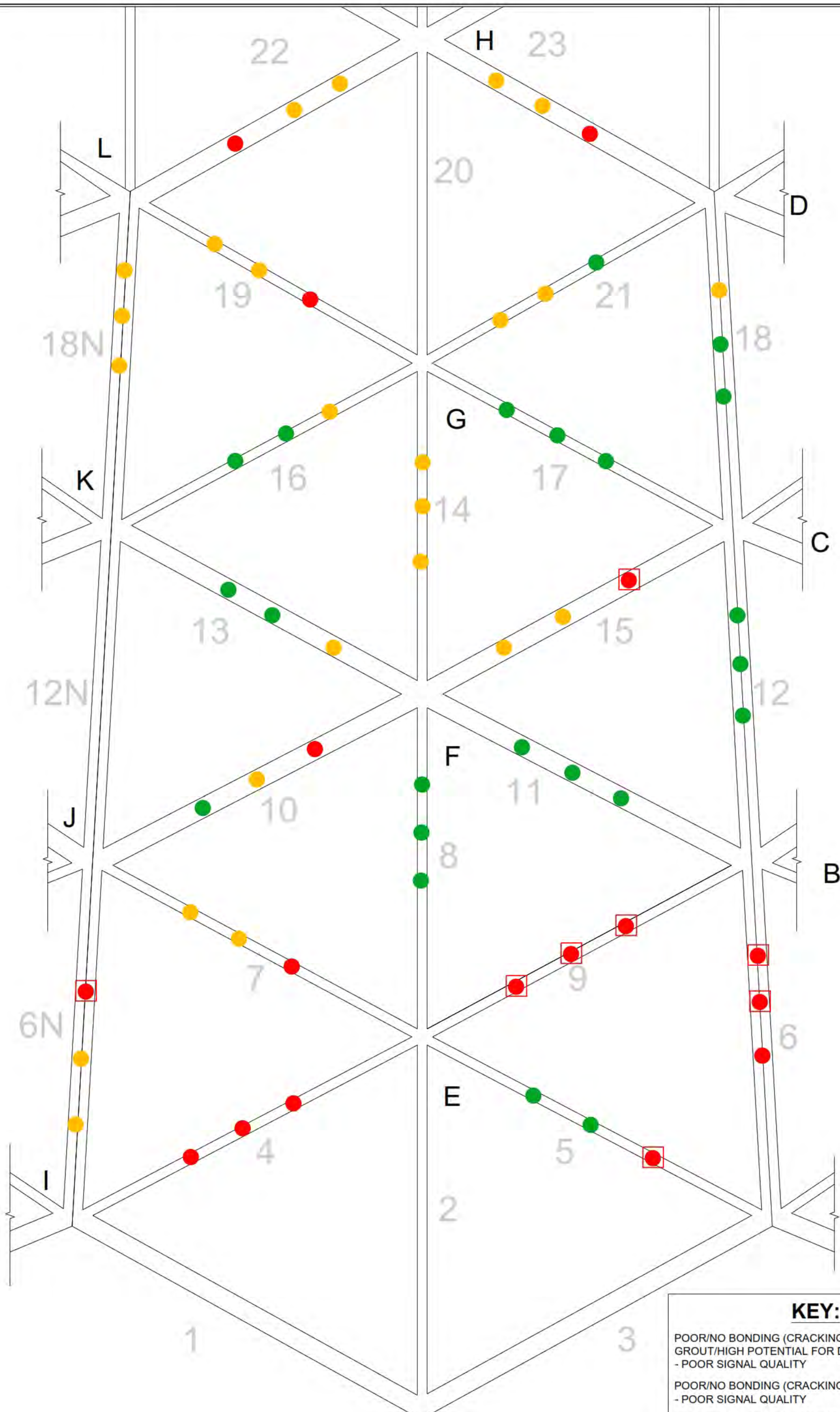
#	DATE	BY	DESCRIPTION



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PARTIAL BONDING (CRACKING/POOR GROUT) - FAIR SIGNAL QUALITY	
WELL-BONDED - GOOD SIGNAL QUALITY	

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SUITE 200B
TAMPA, FL 33610
(813) 501-0050
WWW.VCSERVICES.COM
FL CA # 30851

ELEMENT PLATE OF DOME M

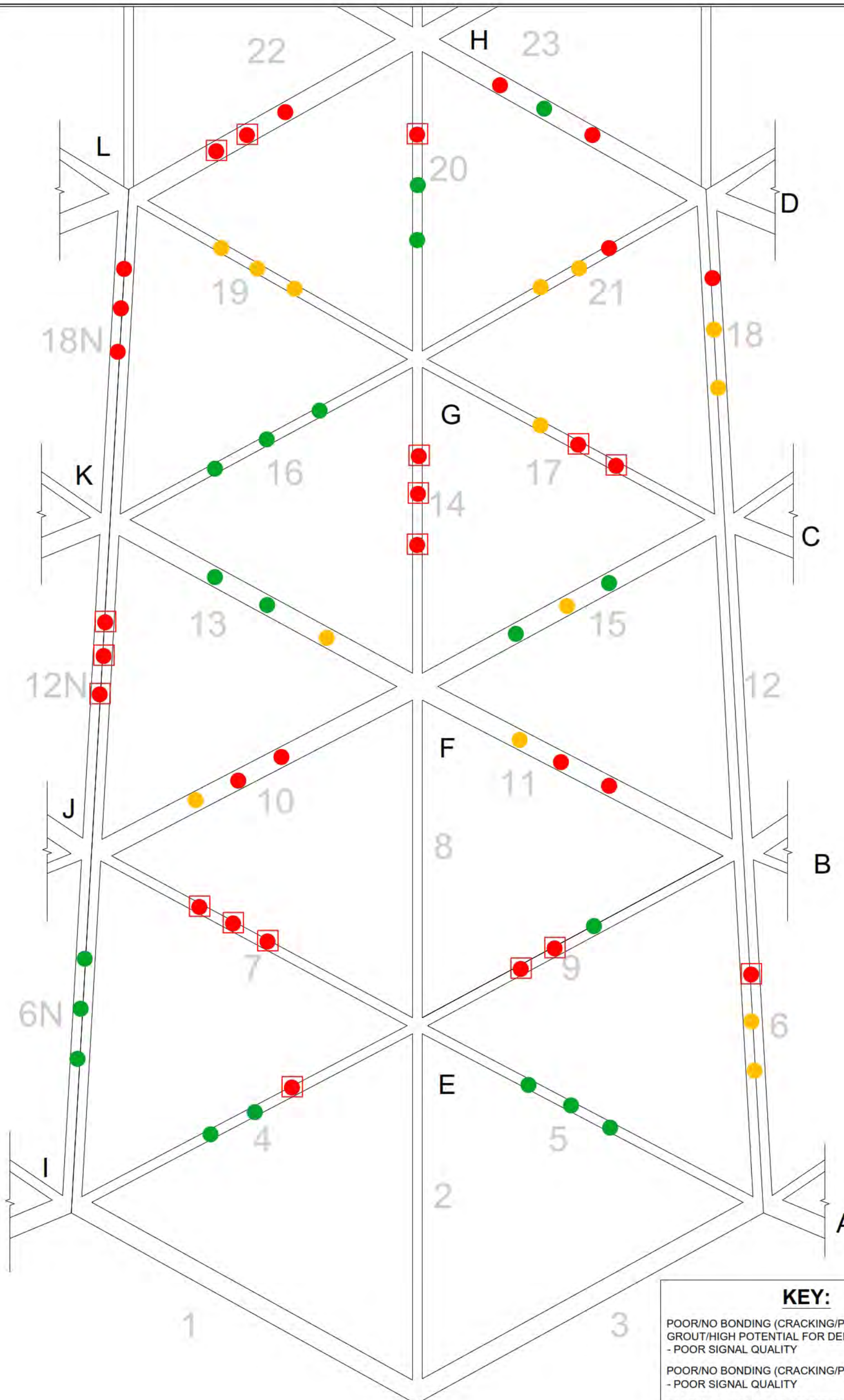
MILWAUKEE DOMES

MILWAUKEE, WI

VCS

DRAWING REVISIONS

#	DATE	BY	DESCRIPTION



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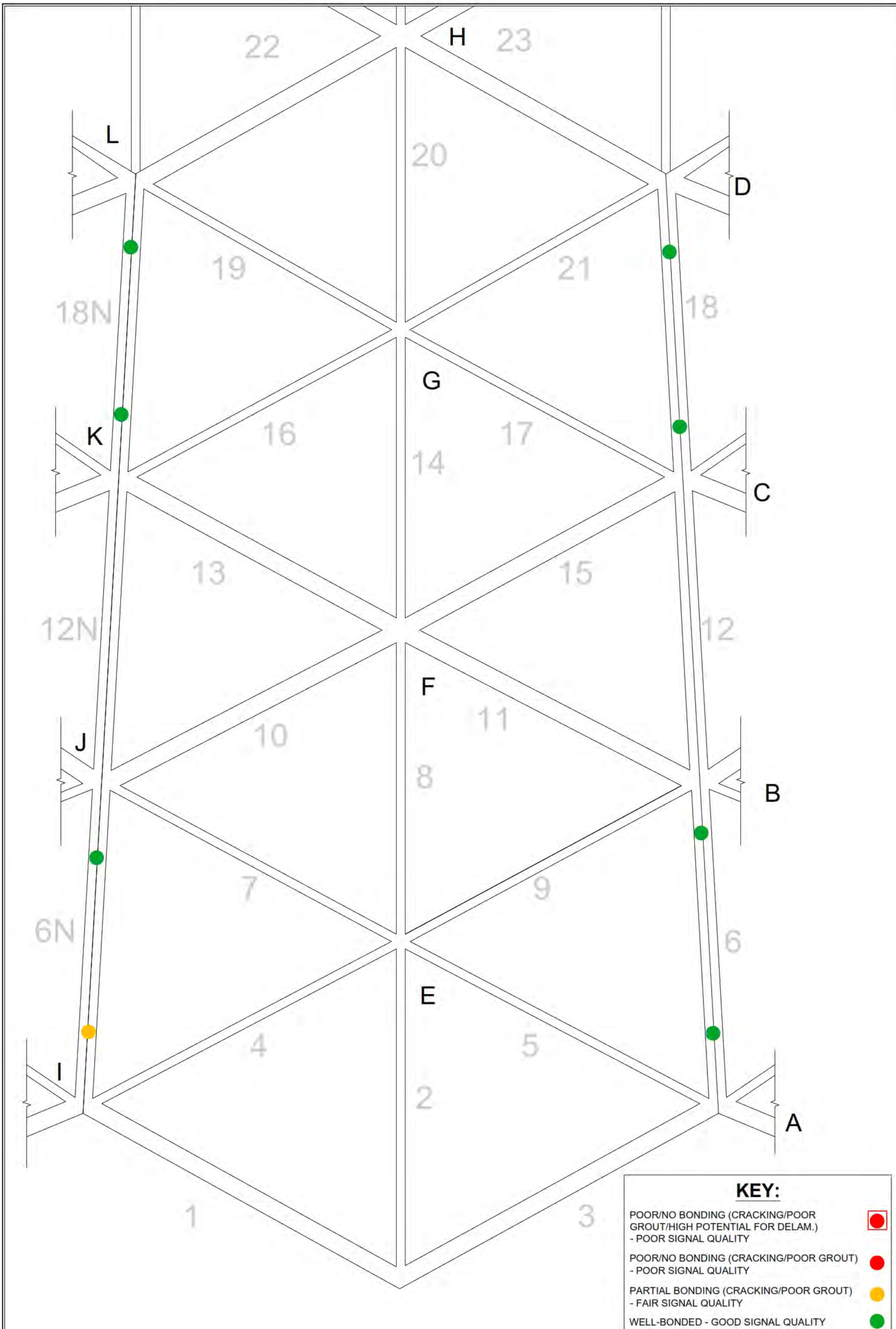
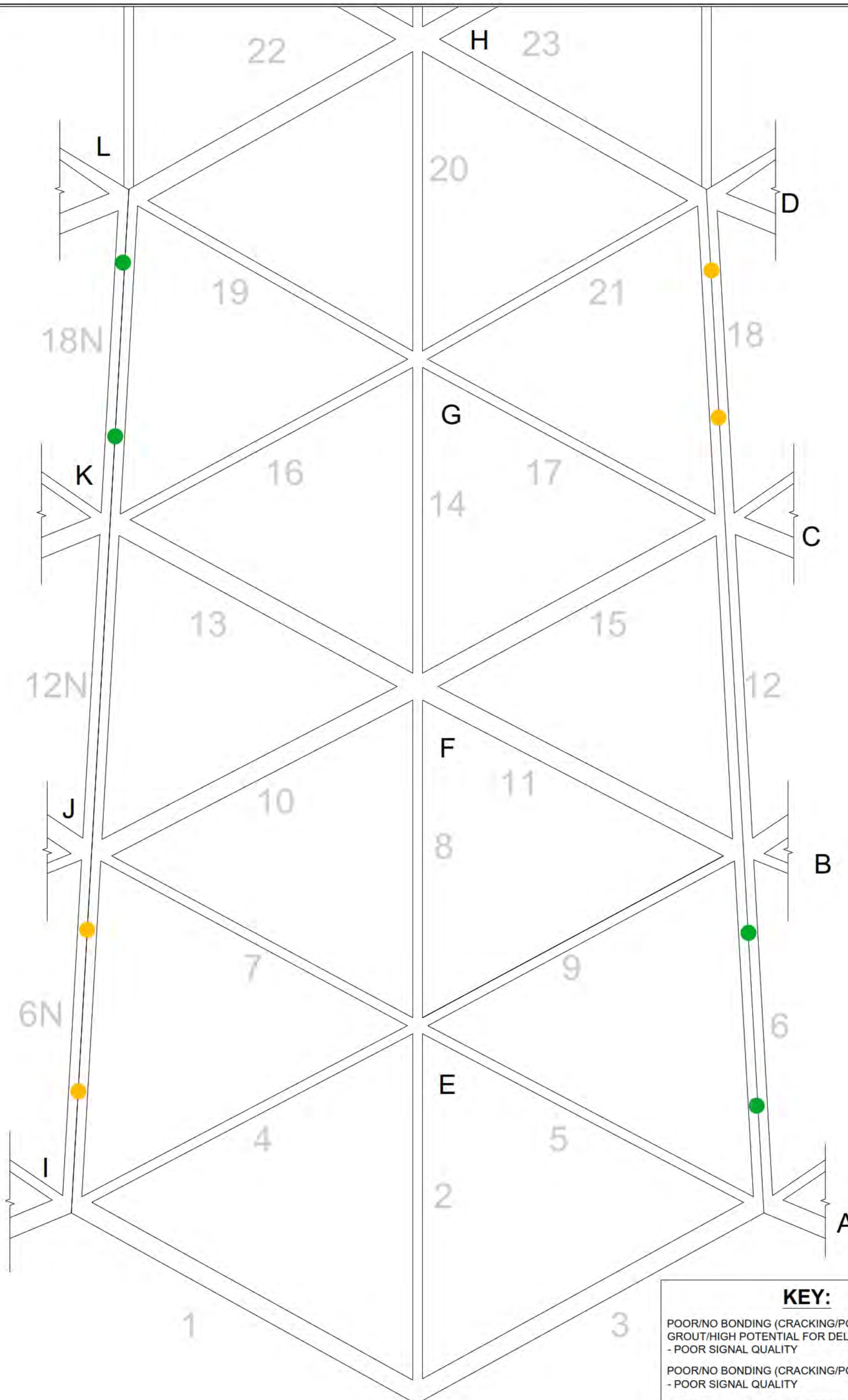
POOR/NO BONDING (CRACKING/POOR GROUT) - POOR SIGNAL QUALITY	Red dot
PARTIAL BONDING (CRACKING/POOR GROUT) - FAIR SIGNAL QUALITY	Yellow dot
WELL-BONDED - GOOD SIGNAL QUALITY	Green dot

PROJECT NO. F19034WI	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	ELEMENT PLATE OF DOME Q	**MILWAUKEE DOMES** MILWAUKEE, WI	VCS	DRAWING REVISIONS
DRAWING NO. 9					# / DATE / BY / DESCRIPTION



PROJECT NO. F19034WI DRAWING NO. 13	VECTOR CORROSION SERVICES, INC. 8413 LAUREL FAIR CIRCLE SUITE 200B TAMPA, FL 33610 (813) 501-0050 WWW.VCSERVICES.COM FL CA # 30851	GROUT POCKETS OF DOME M	**MILWAUKEE DOMES** MILWAUKEE, WI	VCS	DRAWING REVISIONS # DATE BY DESCRIPTION



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POOR/NO BONDING (CRACKING/POOR GROUT/HIGH POTENTIAL FOR DELAM.) - POOR SIGNAL QUALITY	Red dot in a red box
POOR/NO BONDING (CRACKING/POOR GROUT) - POOR SIGNAL QUALITY	Red dot
PARTIAL BONDING (CRACKING/POOR GROUT) - FAIR SIGNAL QUALITY	Yellow dot
WELL-BONDED - GOOD SIGNAL QUALITY	Green dot

PROJECT NO.
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FL CA # 30851

GROUT POCKETS OF DOME Q

MILWAUKEE DOMES

MILWAUKEE, WI

DRAWING REVISIONS

#	DATE	BY	DESCRIPTION