

Appendix F

Topographic Survey Data Report and Bank Features

1 Introduction

The topographic survey of the Lower Duwamish Waterway middle reach was performed as part of the Pre-Design Investigation Phase II work. The results of the topographic survey supplemented data obtained from previous bathymetric surveys and light detection and ranging (LiDAR) elevation data from King County that comprised elevation ranges above approximately +4 feet mean lower low water (MLLW). The topographic survey was intended to collect two types of information from the remedial action level (RAL) exceedance areas adjacent to banks: 1) detailed elevation contours and 2) extents of features (e.g., structures, bank armoring, woody vegetation). Both types of information could affect the design and implementation of remedial actions. The survey was performed at low tide when necessary to obtain topographic data overlapping with bathymetric survey data, and to the top of bank or, for lower banks, to approximately 50 feet landward of mean higher high water.

The topographic survey was performed as described in the *Quality Assurance Project Plan Addendum: Pre-Design Surveys of the Lower Duwamish Waterway Middle Reach* (Anchor QEA and Windward 2021) and the PDI QAPP Addendum Nos. 1 and 2 for Phase II (Anchor QEA and Windward 2024a, b). The horizontal datum for this survey is North American Datum of 1983, 2011 adjustment (NAD83/2011), State Plane Coordinate System, Washington North Zone, measured in U.S. Survey Feet, and the vertical datum for this survey is MLLW (NAVD88 +2.34 feet).

The survey was performed using the two methods described in the following section: traditional land-based surveying and photogrammetric surveying. The photogrammetric method was performed on June 6 and 8, 2024; upland control points were surveyed via traditional land-based methods on June 24, 2024. Additional land-based surveying was conducted from August 19 through 23, 2024. Combined elevation data are presented in main report Maps 2-8a through 2-8e.

2 Survey Methods

2.1 Photogrammetric Survey

Stereo photogrammetric mapping utilizes available data from field survey, public source LiDAR (April 2021), and manual photogrammetry to create a continuous surface that represents a site's topography as accurately as possible. Imagery for the topographic survey was acquired on June 6 and 8, 2024, using a gyroscopically stabilized Vexcel© UltraCam Falcon precision digital imaging sensor. The survey met or exceeded requirements of the American Society for Photogrammetry and Remote Sensing's Edition 2, Version 2 of the *ASPRS Positional Accuracy Standards for Digital Geospatial Data* (2024), as follows:

- Planimetric data: 6-cm accuracy class (RMSE_x and RMSE_y)
- Elevation data: non-vegetated, 10-cm accuracy class (RMSE_z)
- Orthoimage data: 12-cm accuracy class (RMSE_x and RMSE_y or 2 pixels)

Detailed information regarding the photogrammetric survey is provided in Attachment F-1.

2.2 Traditional Land-based Topographic Survey

Traditional land-based topographic surveying was performed to supplement photogrammetric data for areas obscured by physical obstructions (e.g., 1st Avenue S. bridge, areas of dense vegetation) using global positioning system (GPS) and total station instruments. True North established multiple control points at each RAL exceedance area where topographic surveying was performed using the previously established control network. Using GPS techniques, the geodetic control survey was conducted from monuments with published positions and elevations (see Attachment F-2).

The equipment used for the survey and the associated precision of each instrument are as follows:

- Leica TS16 (Total Station): horizontal and vertical of precision 3" (1mgon)
- Leica GS16 (GPS RTK Unit): horizontal precision of 8.0 mm +1 part per million and vertical precision of 15 mm +1 part per million.
- Leica LS10 (Digital Level with Bar Code Rod): vertical precision of 0.3 mm.

Data were collected on a 25-foot, grid-like pattern, as well as at break lines (tops and toes of slopes) and significant changes in existing surfaces. Extents of significant surface bank features (e.g., structures, bank armoring, vegetation, utilities, debris) were determined by taking survey shots at corners of rectilinear features or at changes of curvature for curvilinear features.

3 Deliverable

Topographic data were used to develop surface contours for each of the surveyed areas. The results of the topographic survey were provided in a drawing file and a coordinate file. The drawing file displays the topographic contours and limits of surface features identified as potentially significant during the initial site visit.

4 Signature

SURVEYOR'S CERTIFICATE

THIS MAP CORRECTLY REPRESENTS A SURVEY MADE BY ME OR UNDER MY DIRECTION IN CONFORMANCE WITH THE REQUIREMENTS OF THE SURVEY RECORDING ACT AT THE REQUEST OF

ANCHOR QEA

IN APRIL, 2025.

SIGNED

Ronnie Joann Miller
RONNIE JOANN MILLER

CERTIFICATE NO. 20118394



5 References

- Anchor QEA, Windward. 2021. Quality assurance project plan addendum: pre-design surveys of the Lower Duwamish Waterway upper reach. Final. Submitted to EPA June 25, 2021. Anchor QEA and Windward Environmental LLC, Seattle, WA.
- Anchor QEA, Windward. 2024a. Pre-Design Investigation Quality Assurance Project Plan Addendum No. 1 for the Lower Duwamish Waterway Middle Reach - Phase II Sampling. Final. Anchor QEA and Windward Environmental LLC, Seattle, WA.
- Anchor QEA, Windward. 2024b. Quality assurance project plan addendum No. 2 for the Lower Duwamish Waterway middle reach - Phase II sampling for the Inlet at RM 2.2W. Draft. Submitted to the US Environmental Protection Agency April 19, 2024. Anchor QEA and Windward Environmental LLC, Seattle, WA.
- ASPRS. 2024. ASPRS Positional Accuracy Standards for Digital Geospatial Data. Edition 2, Version 2. Photogrammetric Engineering and Remote Sensing. American Society for Photogrammetry and Remote Sensing.

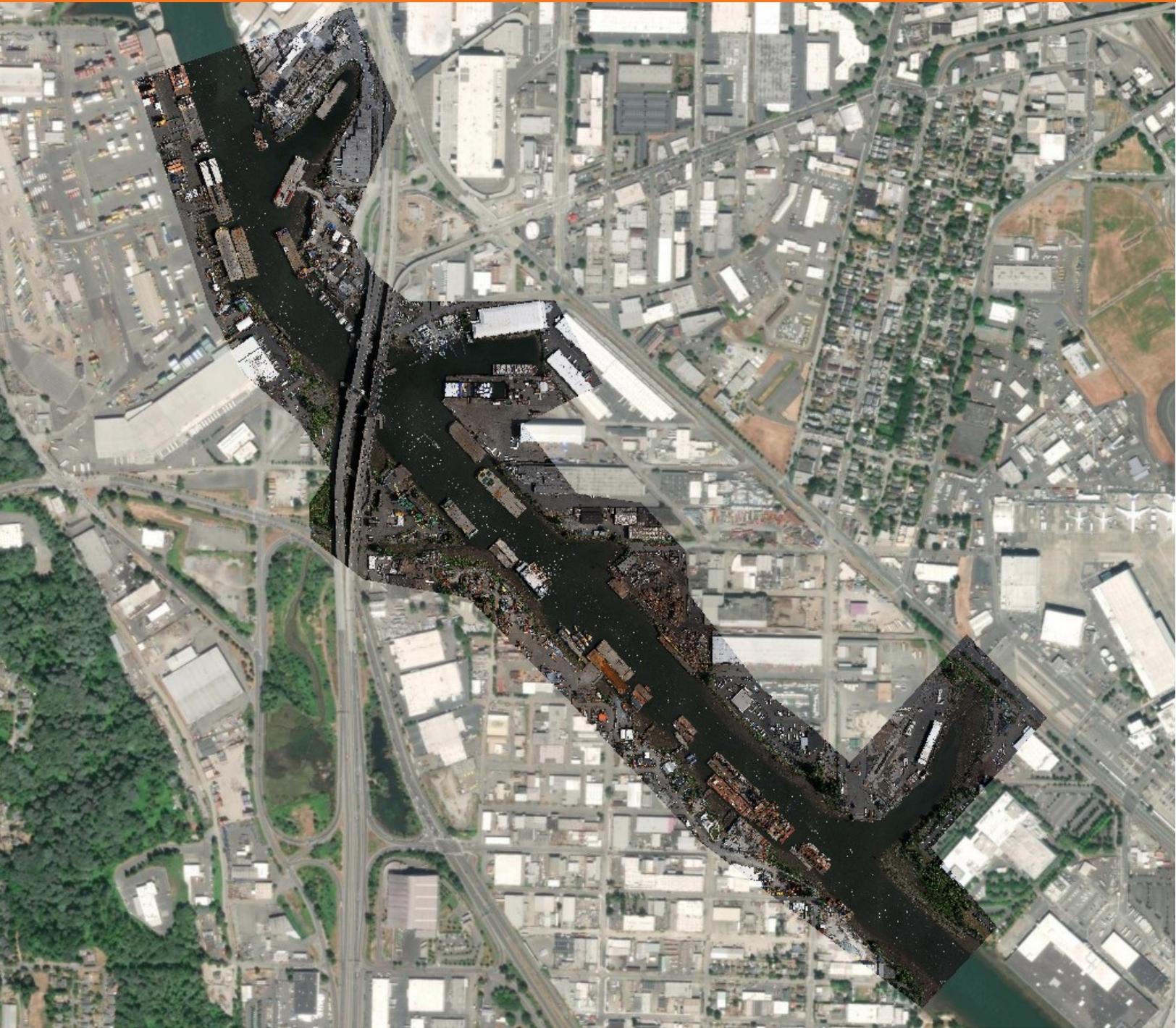
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Attachment F-1

Photogrammetric Survey Report

LDW-Middle Reach

April 2025



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Project Summary

In June 2024, Miller Creek Associates (MCA) acquired aerial imagery for the LDW Middle Reach project along the Duwamish River near Seattle, WA. Imagery was acquired at low tide to allow for high amounts of shoreline visibility. Ground control was provided by True North Land Surveying for georeferencing of the project imagery. MCA prepared 1'=20' topographic mapping for seven distinct areas throughout the study reach. MCA also prepared 0.1' pixel orthophotos and a 2.5D colorized point cloud for the entire area of photographic coverage. After the initial effort, the mapping area was expanded to cover the expanse of shoreline covered by the imagery.

Project Details	
Total Acreage of topographic mapping	155
Imagery Flight Date	June 6 th and June 8 th , 2024
Coordinate System	Washington State Plane North Zone
Horizontal Datum	NAD83/2011
Vertical Datum	NAVD88
Unit of Measure	US Survey Foot
Imagery Sensor	Ultracam Falcon M1
Imagery GSD (Feet)	0.054
Mapping Scale	1"=20'
Contour Interval (Feet)	0.5
Final Orthophoto Resolution (Feet)	0.10'

Table 1: Project Details

Image Acquisition

A gyroscopically stabilized Ultracam Falcon, mounted in a fixed-wing aircraft was utilized for the flight. The flight plan was originally designed designed for 0.06-foot GSD imagery with 60% forward overlap and 50% lateral overlap (sidelap) to maximize the quality of the point cloud.

The project area is in the midst of complex airspace, situated near both King County International (Boeing Field) and Seattle-Tacoma International Airports. After negotiation with both towers, it was determined the best way to manage the airspace was to have us reduce the altitude of our flight lines. This resulted in the capture of slightly higher resolution imagery (0.05-foot).

Airborne GPS and IMU data were acquired during flight to ensure a solid aerotriangulation solution given the considerable amount of water included in the area of interest.

The image data was acquired on June 6 and 8, 2024. Seven of the eight flight lines were acquired on June 6, but air traffic control (ATC) required the flight crew to exit the airspace before the mission could be completed. The final flight line was flown on June 8.

The possible dates for the acquisition of the imagery included particularly low (< -2-foot) tidal elevations, and the imagery acquisition was planned for acquisition within +/-2 hours of the low tide time.

Project Setup and Aerotriangulation (A/T)

After primary image data acquisition, the raw data are processed through Ultramap software to create the final RGB 16bit, 3 band imagery. This process includes relative adjustments between flight strips, dodging, burning and overall color corrections.

Upon receipt of the complete imagery, MCA performed a standard QC to ensure the imagery was complete and correct. GSD was tested to ensure flying height was correct. Overlaps were checked to ensure complete coverage. Upon acceptance of the imagery, the A/T process is started.

MCA utilizes Inpho Match A/T software. The A/T processing was typical, and performed as expected. For more details about the A/T solution, see *"240503_LDW_MatchAT_Report.pdf"* attached to this document.

Photogrammetric Mapping

MCA produced the topographic mapping using a combination of public source lidar data, field surveyed topographic measurements, and photogrammetrically collected breaklines and masspoints. The public source lidar data used for the project was acquired in April, 2021.

For the initial mapping effort, metadata attributes regarding data source were not retained. Thus, we are only able to differentiate the original project's ground points as being either the combined lidar/photogrammetrically measured data, or the field survey points (TP-MASS-SPEC-LIN).

The bare earth lidar points were thinned to a manageable density for use in CAD. In areas showing variance between the lidar data and the project imagery, the lidar data was removed and a combination of photogrammetric point cloud data and manually collected photogrammetric data was used in its place. The photogrammetric data was selected for use because it was visibly less "noisy" when viewed in stereo, and the photogrammetric measurements were generally of higher accuracy.

The field surveyed ground points were imported into the stereo CAD environment for coincident viewing with the other data sources. The field data was very helpful in building a complete tin in areas of lower confidence (vegetated areas). The stereo review evaluated all data against the project imagery and utilized the best source of data for a given area.

In addition to the elevation data, planimetric features typically shown on 1"=20' scale maps were collected. Cartographic edit was performed to assure readability.

Orthophoto

A 0.1' pixel orthophoto was generated of the project area.

Quality Control

MCA performs a comprehensive quality control assessment of both the processes and of the data from before flight, during production and when project deliverables are complete. All datasets were checked against each other for consistency, accuracy and completeness. Specific quality control checks included the following:

1. QC checks are made of all incoming data including imagery, AGBPS, and ground control. The checks ensure these data fit well with the other project inputs and meet the requirements of the project.
2. Stereo checks are performed to verify data collection is complete and accurate.
3. Inspections are made of all deliverables for completeness and accuracy. They include:
 - a. Map projection check
 - b. Data completeness check
 - c. Verification all deliverables have been produced and meet the requirements of the project

Accuracy Assessment

To perform a statistically significant accuracy assessment for digital geospatial data, a minimum of 30 well distributed, higher accuracy check points are needed. While there are more than 30 field surveyed points within the project area, they are clustered around just a few not-well-distributed locations. Further, the ground shots were generally incorporated into the final digital terrain model, voiding their potential use as a check point for accuracy assessment purposes.

Although a robust, independent, empirical accuracy assessment was not performed for this data set, we can draw some inferences.

The project's flight plan and ground control layout were originally designed to support mapping meeting or exceeding the ASPRS Positional Accuracy Standards for Digital Geospatial Data (Edition 2, Version 1.0, August 23, 2023) as follows:

- Planimetric data – 0.2-ft accuracy class (RMSE_x and RMSE_y)
- Elevation data – non-vegetated – 0.15-ft accuracy class (RMSE_z)
- Orthoimage data – 0.3-ft accuracy class (RMSE_x and RMSE_y)

By flying the project at a lower altitude than originally planned, the resulting image ground sample distance (GSD) is finer. As a result, we would expect final map accuracies to be better than those indicated above, especially if other error budget constituent inputs meet their expected accuracies. The very clean A/T, which combines these various inputs, indicates accuracies better than those above can be expected.

Project Deliverables

Following is a list of deliverables for the project:

- Planimetric mapping at 1"=20' scale in AutoCAD format
- Contours at 0.5-foot intervals in AutoCAD format
- Digital terrain model in LandXML format
- Project metadata PDF format
- Project report in PDF format

Challenges

The main challenges for this project involved coordinating the imagery flights with nearby ATC authorities. Because of the proximity to busy airports, ATC determined the best way to maintain safe airspace would be for our mission to be flown at a lower altitude. By revising the flight plan with a lower altitude, more images were needed to cover the project area.

By flying as low as designed into the new flight plan, the reduced spacing/timing between images can exceed the minimum cycle time of the sensor, which leads to skipped images. To mitigate this potential issue, the pilot flew all the flight lines in the same direction, into the wind. This reduces ground speed and increases the time between exposures. It also increases the time needed to capture the imagery.

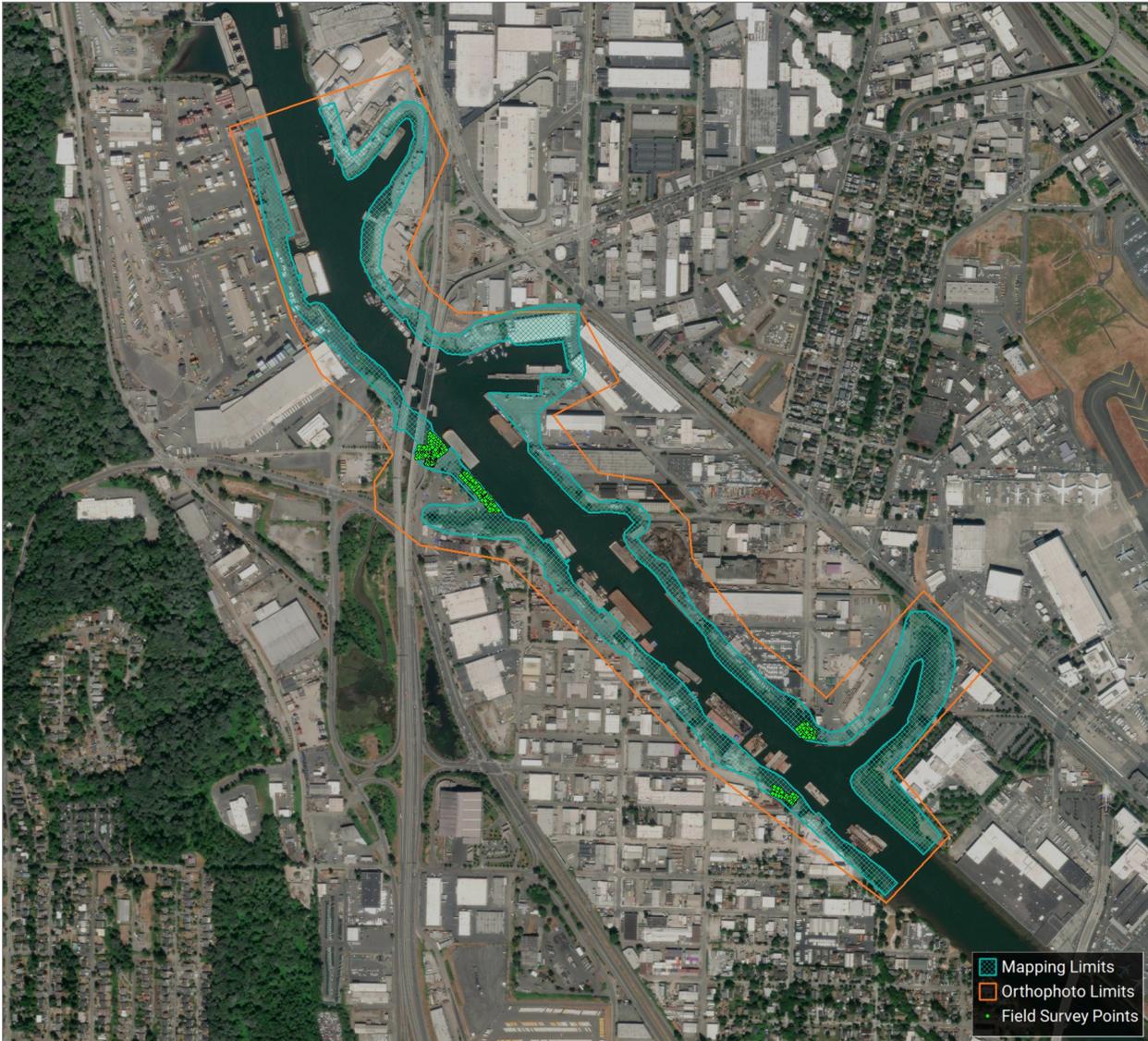


Exhibit 1: Project Limits and Location of Field Survey Data

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Attachment F-2

Geodetic Control Survey Notes

Duwamish Waterway

CP-1

Start = 10:27
End = 10:42

S. Seattle BM 3745-4302

N: 198133.8310
E: 1272493.4610
EL: 15.662 (MLLW)
EL: 13.322 (NAVD88)

JL DARLING LLC
Tacoma, WA, USA • jldarling@jldarling.com

19-24 4-5-19 KH JS 5/

No 302

Find: COS BM 3745-4302
2" brass men w/punch
Point is 15' +/- N. of
the Int mic @ 8th
Ave So. of S. Portland St.
Point is on E conc side
walk, 24' NE of a CB, 35'
W. of a picnic bench.

CITY OF SEATTLE

3745
o
4302

SURVEY

John Darling

Duwamish Waterway

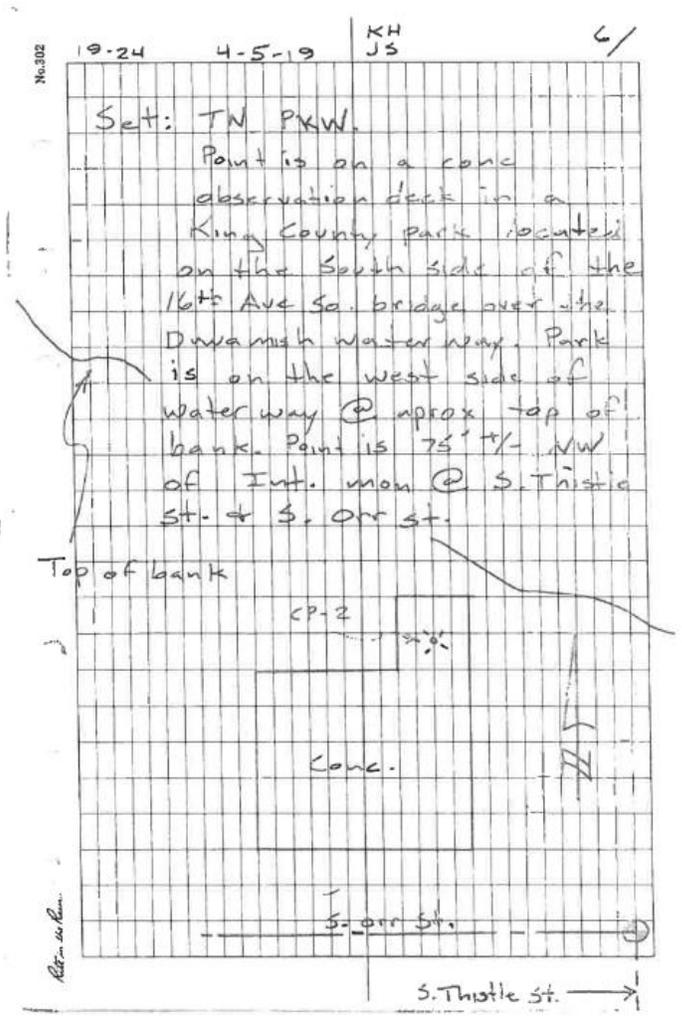
CP-2

Start = 11:08

Revised by 3/9/24-DZ
IN = 312.2 (approx)

N: 196306.7280
E: 1274553.8670
EL: 15.376 (NAVD88)
EL: 17.716 (MLLW)

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Duwamish Waterway

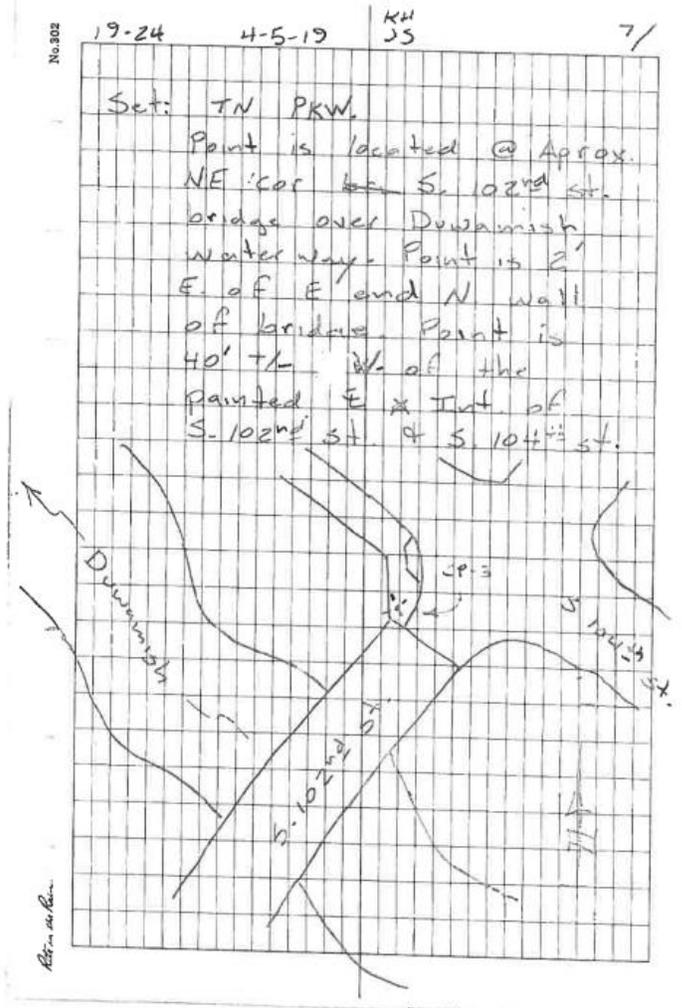
CP-3

Start = 12:13

Recon. 1934-35
In S. Cor. to L&P

N: 189971.2850
E: 1278959.0970
EL: 21.316 (NAVD88)
EL: 23.456 (MLLW)

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Duwanish Waterway

CP-4

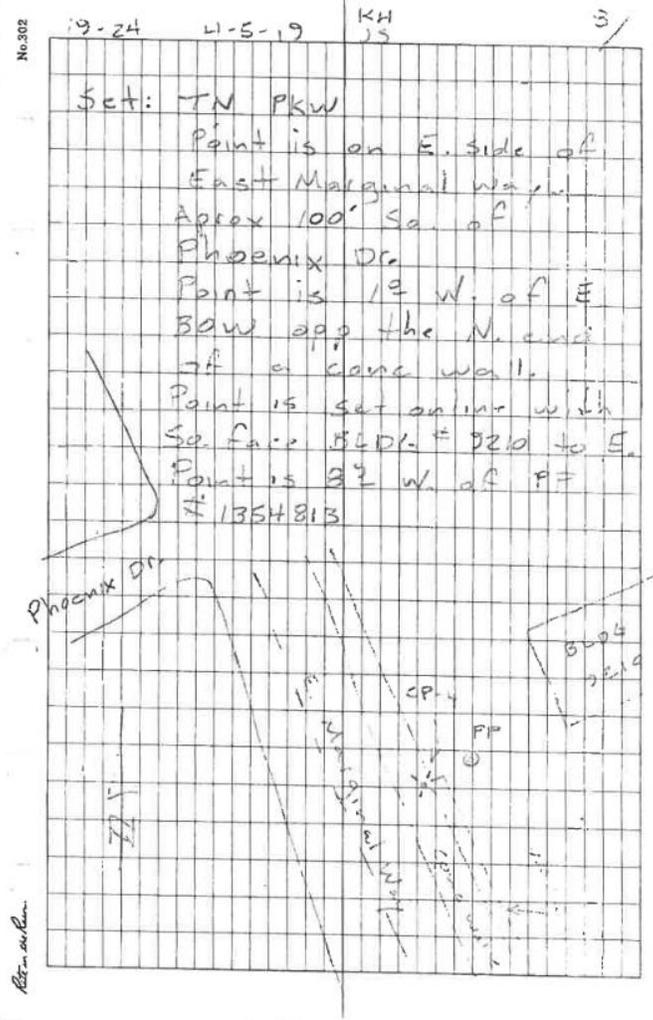
Start = 12:41

GPS

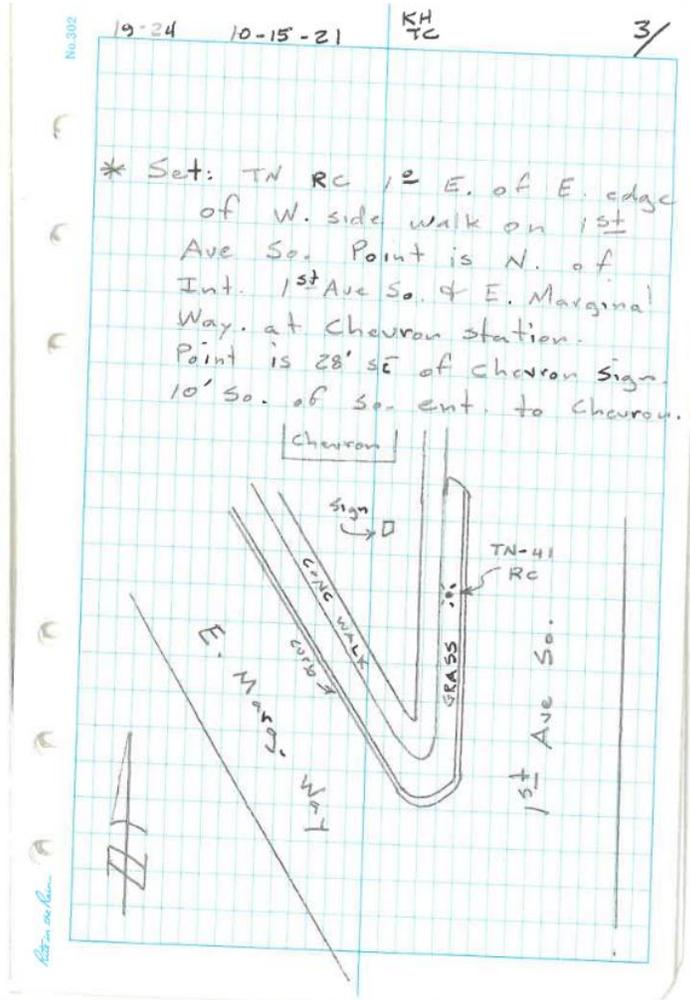
N: 199421.7090
E: 1278250.4770
EL: 18.743 (NAVD83)
EL: 21.083 (MLLW)

9.3

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PT	LDW	New	GPS	Control
	Red	Code		Desc.
CP-41	ZM	RC		
<p>N: 203955.2830 E: 1269749.3010 EL: 16.168 (NAVD86) EL: 18.508 (MLLW)</p>				



LDW New GPS Control

PT	Red	Code	Desc
CP-42	ZM	PKW	

N: 201801.3310
 E: 1270041.6060
 EL: 12.365 (NAVD88)
 EL: 14.705 (MLLW)

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