DISPERSANT EFFECTIVENESS TESTING IN COLD WATER ON FOUR ALASKAN CRUDE OILS

For

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Executive Summary

In the winter of 2003, shortly after dispersant testing began at Ohmsett, five Alaskan crude oils including Alaskan North Slope (ANS), Endicott, Pt. McIntyre, Northstar and Middleground Shoals were tested in cold-water conditions. Corexit 9527 dispersant was used in all of these experiments as this is the dispersant stockpiled in Alaska for spill response. The National Research Council of the National Academies (NRC 2005) reviewed the methods used and the results of this early test program and reported that the results should be used with caution because in two of the twelve tests the oil had to be warmed prior to discharge in order to reduce its viscosity for pumping in the cold conditions. The NRC recommended repeating the work with an improved oil distribution system so the oil could be applied to the waters surface without warming. Since the 2003 work was completed a number of improvements have been made in the dispersant effectiveness testing methods, protocols and capabilities at Ohmsett. These improvements include:

1) A new oil distribution system that no longer requires that viscous oils be heated prior to discharge.
2) A longer and wider test area has been established for dispersant effectiveness testing.
3) Tank turbulence measurements are now routinely made using a Sontek Acoustic Doppler Velocimeter purchased for this specific purpose at Ohmsett.
4) Dispersed oil concentration and particle size measurement is now a standard component of the dispersant effectiveness program using the LISST 100 particle size analyzer purchased by MMS for this specific purpose at Ohmsett.
5) Methods have been developed to complete on-tank long-term weathering and emulsion formation on the Ohmsett test tank or using a batch process off the tank.

The physical and chemical properties of Alaskan crude oils have changed since the 2003 tests. As seen in Table S1, the densities of all but the Endicott oil are lighter in the more recent oil samples. The significant improvements in the dispersant testing methods and equipment at Ohmsett combined with the changing properties of Alaskan crude oils provided the justification for re-testing the dispersibility of Alaskan oils in cold waters.

Four Alaskan crude oils were used in the 2006 tests at Ohmsett that were conducted over a three week period in late February and early March. They were Alaskan North Slope (ANS), Endicott, Pt. McIntyre, and Northstar crude oils. The oils were tested fresh, weathered by removal of light ends using air sparging and weathered by placing the oils on the tank in both breaking wave conditions (high-energy) and non-breaking waves. Physical properties of the test oils are provided in Table S1. The densities of the fresh oils used in the 2003 test program are also provided for comparison.

Table S1. Physical Properties of Test Oils

Oil	2003 Test Oils	2006 Test Oils					
	Density (mg/l) 25 ºC	Density (mg/l)	Viscosity (cP) 100s^{-1}, 1ºC	Oil Loss (% Volume)	Oil Loss (% Weight)	Wave Duration (min)	Water Content (%)
Alaska North Slope							
Fresh	0.873	0.863	22	0	0	-	0
Air sparged	0.912	0.887	93	15.3	12.7	-	0.2
On-Tank Lo-Energy		0.901	203	25.1	na	66	5
On-Tank Hi-Energy		0.903	200	26.5	na	49	16
Endicott							
Fresh	0.878	0.9018	270	0	0	-	0.2
Air sparged	0.914	0.917	644	20.1	18.6	-	0
Northstar							
Fresh	0.812	0.8025	7.6	0	0	-	0
Air sparged	0.864	0.839	36	34.5	30.5	-	0
On-Tank Lo-Energy		0.842	116	37.6	na	80	40
On-Tank Hi-Energy		0.843	143	38.6	na	37	48
Pt. McIntyre							
Fresh	0.890	0.861	34	0	0	-	2
Air sparged	0.902	0.880	76	12.5	10.6	-	0.5
On-Tank Lo-Energy		0.884	214	15.9	na	65	45
On-Tank Hi-Energy		0.898	695	27.6	na	156	48

A total of 10 control (no dispersant applied) and 15 Corexit 9527 dispersant applied tests were completed in the test program. Corexit 9527 dispersant was used in all of the experiments, as this is the dispersant stockpiled for oil spill response in Alaska.

The test conditions and estimated Dispersant Effectiveness (DE) for all of the large-scale tank tests are summarized in Table S2. Refer to Section 4.1 for a detailed description of the contents of Table S2.

With the exception of two control runs with the light Northstar oil 80 to 90% of the spilled oil in control runs (no dispersant applied) was accounted for by either oil collection or evaporation estimates. The high oil losses for the Northstar control runs can be attributed to natural dispersion/dissolution of this very light oil.

In the “dispersant applied” tests the “% Dispersed / Lost” (%D/L) estimates were all very high. There were ten tests with 95% or higher values, four tests 90% or higher and one test at 85%, with this being the lowest value.

The dispersant effectiveness (DE) “control adjusted” data column is the %D/L estimate for each dispersant applied run minus the %D/L estimate for the control run using the same oil. This number can be regarded as the *minimal* incremental benefit (dispersion) achieved through the application of chemical dispersant to the oil slick after the control test results are taken into account. The calculated DE values should be viewed as the minimal benefit derived from the use of dispersants in these tests. The actual dispersant effectiveness could easily be as high as the %D/L results reported for those tests where immediate and complete dispersion of the oil occurs before any oil has the opportunity to reach the tank side walls or end booms or evaporate. The DE (control adjusted) values for the dispersant applied runs indicate that the application of dispersant minimally improved the dispersion of the oils in all but one test case by 60% or more with most tests achieving an improvement greater than 75%. The Corexit 9527 dispersant was effective in all of the tests and resulted in very high overall oil removal in most tests even in the cold temperatures prevalent during the test program.

The results for the control tests were very similar for the 2003 and 2006 tests. In all of the control tests, between 0% and 20% of the oil applied was dispersed into the water column or lost (D/L) to side walls.

Table S2. Ohmsett Tank Dispersant Effectiveness (DE) Test Results Summary

Oil	Initial Oil Viscosity (cP)	Initial Oil Water Content (%)	Air Temp °C	Water Temp °C	Oil Temp °C	Dispersant Temp °C	Oil Volume (liters)	Oil Thickness (mm)	DOR	% Collected	% Evaporated	% Dispersed / Lost	DE (Control Adjusted)	Links to Video Segments	Test #
Alaska North Slope															
Fresh	22	0	-2.7	-2	7.8	-	74.8	0.9	Control	60.3	19.3	20.4	-	467 Test 2.mpg	2
Fresh	22	0	1.2	0.3	-1.7	3.9	75.7	1.2	38	5.3	-	94.7	74.3	467 Test 3.mpg	3
Air sparged	93	0.2	3.3	-0.6	-0.6	-	75.9	1.1	Control	77.9	9.6	12.6	-	467 Test 5.mpg	5
Air sparged	93	0.2	6.2	0.0	2.2	5.0	50.4	1.1	26	2.7	-	97.3	84.7	467 Test 6.mpg	6
On-Tank Lo-Energy	203	5	-1.9	0.0	-4.4	-1.7	69.7	2.8	28	2.6	-	97.4	84.8	467 Test 10.mpg	10
On-Tank Hi-Energy	200	16	0.5	0.0	-0.6	3.3	62.8	2.6	25	3.4	-	96.6	84.0	467 Test 9.mpg	9
On-Tank Hi-Lo Mix	256	14	8.6	2.8	3.3	7.2	65.2	1.2	21	1.1	-	98.9	86.3	467 Test 23.mpg	23
Endicott															
Fresh	270	0.2	0.5	0.0	0.0	-	72.5	1.2	Control	61.8	24.7	13.5	-	467 Test 8.mpg	8
Fresh	245	0.2	7.1	2.8	3.3	7.2	79.8	3.3	27	0.4	-	99.6	86.1	467 Test 17.mpg	17
Air sparged	772	0	-0.7	0.0	-1.1	-	73.4	3.2	Control	71.5	5.7	22.8	-	467 Test 7.mpg	7
Air sparged	644	0	-0.1	0.0	-2.8	0.0	73.4	3.8	40	14.9	-	85.1	62.3	467 Test 11.mpg	11
Air sparged	644	0	15.7	3.3	10.6	13.9	77.0	2.5	17	8.9	-	91.1	68.3	467 Test 25.mpg	25
Northstar															
Fresh	7.6	0	5.6	1.7	0.0	-	80.2	1.6	Control	31.9	45.0	23.1	-	467 Test 13.mpg	13
Fresh	7.6	0	7.3	1.7	2.2	9.4	69.4	1.5	25	3.7	-	96.3	73.2	467 Test 14.mpg	14
Air sparged	36	0	7.3	1.9	-1.7	0.6	75.7	3.2	43	8.9	-	91.1	68.0	467 Test 15.mpg	15
On-Tank Lo-Energy	116	40	2.8	1.1	-1.7	-	47.9	1.9	Control	49.4	12.3	38.3	-	467 Test 12.mpg	12
On-Tank Hi-Energy	143	48	1.6	-2.8	-2.8	-	39.9	1.7	Control	24.2	17.2	58.6	-	467 Test 18.mpg	18
On-Tank Hi-Energy	143	48	5.6	2.2	0.0	1.7	38.3	2.4	23	1.7	-	98.3	39.7	467 Test16.mpg	16
Pt. McIntyre															
Fresh	34	2	-2.0	0.0	7.8	-	66.4	2.2	Control	76.3	12.2	11.5	-	467 Test 1.mpg	1
Fresh	34	2	7.6	3.3	5.0	11.7	68.4	1.1	18	0.7	-	99.3	87.8	467 Test 21.mpg	21
Air sparged	76	0.5	0.6	-0.4	-0.6	-	75.3	1.1	Control	68.4	9.4	22.2	-	467 Test 4.mpg	4
Air sparged	76	0.5	5.8	2.8	2.2	8.3	67.8	2.1	18	0.7	-	99.3	77.1	467 Test 20.mpg	20
On-Tank Lo-Energy	214	55	13.7	2.8	2.8	16.7	33.6	1.9	28	1.0	-	99.0	76.8	467 Test 24.mpg	24
On-Tank Hi-Energy	695	48	7.8	2.8	2.2	-	28.0	0.9	Control	19.6	3.8	76.7	-	467 Test 22.mpg	22
On-Tank Hi-Energy	695	48	3.9	2.8	0.6	4.4	39.7	3.5	25	5.9	-	94.1	71.9	467 Test 19.mpg	19

Note: DE is the dispersant effectiveness estimate after accounting for oil lost in the control run.

The estimates of non-control corrected dispersant effectiveness (DE) for the fresh oils were also similar in the two test programs. The fresh ANS and Northstar oils were over 90% dispersed in both programs. The fresh Endicott and Pt. McIntyre oils showed less dispersion in the 2003 tests (about 75% DE versus 99% in 2006) but significant dispersion was recorded for these oils in both test programs.

The DE for air sparged ANS was similar in the two test programs (97% in 2006 versus 85% in 2003). The DE estimates for both air sparged Endicott and Northstar were considerably higher in the 2006 testing when compared to the 2003 results (85+% in 2006 compared to 3% in 2003). Oil property differences due to slightly different weathering conditions or different starting oil properties are a possible explanation for these major differences, especially for the Northstar oil that had a lower density in the 2006 tests (0.838 g/cc versus 0.864 g/cc in 2003). The 2006 results suggest that the window of opportunity for dispersant use on these four Alaskan crude oils may be longer than expected based on the 2003 testing.

Hypertext links are provided in Table S2 to composite video clip segments of each of the tests. The video records can be viewed by double-clicking on a link when accessing this document through MS Word or Adobe Acrobat. The video record for each test includes short video segments that have been merged together into one file to show the progression of the test from the beginning to the end. The video clips provide a good record of the behavior of the oil in each of the tests and it is highly recommended that they be viewed to get a full appreciation of the test program.

In-water oil concentrations and drop size distributions were measured using the LISST 100 particle size analyzer at a depth of 1.5 meters from the calm water surface in up to four passes down the length of the test tank after the oil was discharged. Graphs of the dispersed oil drop size distributions and concentrations are provided in Appendix B.

The in-water oil graphs show the following common themes. In cases where the oil was chemically dispersed (% Dispersed/Lost greater than 85% in Table S2) the oil concentrations in the water column were elevated significantly (40 ppm to 100+ ppm) in the dispersed oil cloud and the oil drop sizes were small (Volume Median Diameters generally less than 50 microns). In control tests oil concentrations generally remained below 20 ppm (as measured by the LISST 100) and where elevated oil concentrations were detected the oil drop sizes were much larger than those measured in the dispersant applied runs.

A Sontek Horizon Acoustic Doppler Velocimeter (ADV) probe was deployed at 1.5 meter depth and used to measure X-Y-Z water velocity fluctuations during each test. The velocity data from all tests was processed to calculate the average turbulent kinetic energy (TKE) as determined by the sum of the velocity variances in x, y, and z divided by 2 (Bradshaw, 1971). The TKE value was determined for up to 4 measurements or data collection bursts in each test and these values were then averaged to determine a final representative TKE for each test. The same wave paddle settings were used to provide mixing during all of the tests (3.5 inch stoke and 35 cpm frequency) and the average TKE for the 25 tests completed was 166 with standard deviation of 40. Different wave energies were used to generate the “On-Tank Lo-Energy” and “On-Tank Hi-Energy” weathered oil samples that were collected from the tank surface and then later used as test oil.

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1.0 Background

The use of chemical dispersants in US waters is achieving a similar status to that of conventional booming and skimming countermeasures. Equipment guidelines currently being proposed by the US Coast Guard mandates that a dispersant application capability must be included in spill response plans for those regions where dispersant pre-authorization has been established and dispersants are included in the plan holder's response capabilities (Summary Report of Public Workshop for Response Plan Equipment CAPs http://www.uscg.mil/vrp/reg/caps.shtml). This includes all US coastal waters with the exception of Washington, Oregon, the Great Lakes, some areas within Long Island Sound and limited areas of Prince William Sound and Cook Inlet in Alaska. When these guidelines are established and industry gears-up its ability to apply dispersants the number of spill incidents where dispersants will be considered will increase. There will be an increased need to know when dispersants will likely be effective on different oil types to assist in the dispersant-use decision-making process.

The Ohmsett test facility is becoming a world leader in realistic dispersant effectiveness testing through the design and development of a calibrated, referenced and realistic test protocol at the facility and subsequent testing under cold and temperate conditions. The National Research Council (NRC) strongly supported the use of wave-tank testing in their recent review of chemical dispersants (NRC 2005) as evidenced in the following quote from the report ".. wave-tank tests are an important tool that can be used to tie the artificialities of laboratory studies to the operational realities of dispersant use in spill response". The Ohmsett facility is the world's largest wave-tank complex presently completing such studies and is the logical venue for bridging the gap between laboratory and field testing.

Five Alaskan crude oils including Alaskan North Slope (ANS), Endicott, Pt. McIntyre, Northstar and Middleground Shoals were tested at Ohmsett for dispersant effectiveness in cold-water conditions in the winter of 2003. Corexit 9527 dispersant was used in all of the experiments as it is the only dispersant stockpiled in Alaska for spill response. The NRC reviewed the methods used and the results of this test program and reported that the results should be used with caution because in two of the twelve tests the oil had to be warmed in order to reduce its viscosity for pumping in the cold conditions. The NRC recommended repeating the work with an improved oil distribution system so the oil could be released without warming. Since the 2003 work was completed a number of improvements have been made in the dispersant effectiveness testing methods, protocols and capabilities at Ohmsett. These improvements include:

1. A new oil distribution system has been installed to permit the controlled release of viscous oils in dispersant effectiveness tests. The 2003 testing on Alaskan oils experienced difficulty in pumping the oils in the cold temperatures. This required that the oil be warmed prior to discharge. The new system has been proven to easily discharge oils with viscosities well in excess of 36000 cP thus eliminating the need to warm the oil for discharge purposes.
2. A longer and wider test area has been established for dispersant effectiveness testing. This reduces the influence of the end containment booms in the testing and eliminates the side booms. The straight walls of the test tank replace the side booms previously used and this reduces oil losses and artificial dispersion due to boom "pumping" action.
3. Tank turbulence measurements are now routinely made using a Sontek Acoustic Doppler Velocimeter purchased for this specific purpose at Ohmsett.
4. Dispersed oil concentration and particle size measurement is now a standard component of the dispersant effectiveness program using the LISST 100 particle size analyzer purchased by MMS for this specific purpose at Ohmsett.
5. Methods have been developed to complete on-tank long-term weathering and emulsion formation on the Ohmsett test tank or using a batch process off the tank. This can be incorporated into a dispersant effectiveness program to investigate the effectiveness of dispersants on oils weathered under more realistic conditions.

The physical and chemical properties of Alaskan crude oils have changed since the 2003 tests. Three of the four oils (ANS, NS and Pt.Mac.) are lighter than they were in the 2003 testing and the Endicott oil is heavier. The significant improvements in the dispersant testing methods and equipment at Ohmsett combined with the changing properties of Alaskan crude oils provided the justification for re-testing the dispersibility of Alaskan oils in cold waters. The new test program was completed at Ohmsett in the last week of February and the first two weeks of March, 2006.

2.0 Ohmsett Dispersant Effectiveness Test Methods

An overview of the dispersant effectiveness (DE) test method used at Ohmsett is provided by first describing the test tank and main apparatus used in the testing. This is accomplished primarily through the use of photos of the equipment used in the dispersant experiments to give the reader an appreciation of the scale of the operation. Methods used to characterize the dispersed oil are then described. Finally, the step-by-step test procedure is itemized. The test procedure has been developed over a period of several years and has been refined from the experiences gained from several earlier dispersant effectiveness test projects (SL Ross 2000a & b, 2002a & b, 2003 a & b, 2004, 2006) and the NRC review comments.

2.1 Major Test Equipment Components

The main equipment components of the DE test procedure include the Ohmsett tank, the wave making system, the main equipment bridge, the oil distribution system, the oil containment boom and the dispersant spray system. Photos of these components are provided in Figures 1 through 5. Additional details concerning this equipment can be found in SL Ross 2002b and 2006. Dispersed oil was characterized using flow-through and in-situ fluorometry, dispersed oil particle size determination and water sampling (for Total Petroleum Hydrocarbon (TPH) determination).

The most recent dispersant effectiveness protocol calls for a single 24 inch boom to be placed across the tank close to the wave paddle at the south end of the tank and two 48 inch booms across the tank about 100 feet from the north end of the tank (see Figure 1). This provides a long and wide test area (approximately 500 feet long and 65 feet wide) with no side booms to minimize the influence of these barriers on the dispersion process. Figure 1 provides a look at the extensive test area from both a south and north vantage point. The wave paddle is shown in Figure 2. Figure 3 shows the main bridge that is used to move equipment and observers along the length of the test basin. The right photo in Figure 3 shows the dispersant spray bar and a scale bar (marked in 1 foot increments) positioned under the deck for use in estimating the oil slick width.

Figure 1. Ohmsett Test Tank with Oil Containment Boom (looking north and then south)

Figure 2. Ohmsett Tank Wave Paddle System

Figure 3. Main Bridge and Bridge with Dispersant Spray Bar & Slick Width Scale

The new oil discharge system shown in Figure 4 includes:

1. a progressing cavity pump (left photo Figure 4 bright green),
2. a pump speed control system,
3. a gravity fed oil hopper supply (white tank above pump),
4. three-inch oil supply lines, and;
5. a stainless steel oil discharge manifold (right photo Figure 4).

Oil is pumped into the hopper from drums or other supply tanks using the progressing cavity pump in reverse. The flow rate of this pump is precisely controlled by altering its rpm. The pump generates 0.19 gallons per minute per revolution of the pump. The quantity of oil discharged from the hopper is measured using a sonic probe mounted above the oil supply. Photographs of the oil supply system and oil discharge header are provided in Figure 4.

Figure 4. Oil Supply System and Discharge Header

The dispersant supply system and operating spray bar is shown in Figure 5.

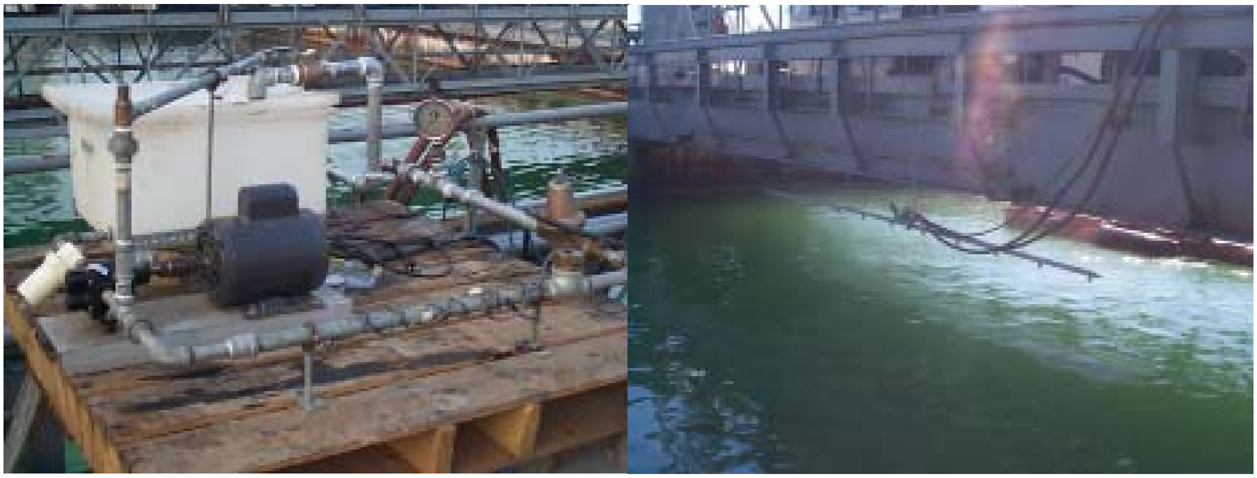

Figure 5. Dispersant Supply Tank and Pump and Dispersant Spray Bar in Operation

2.2 Dispersed Oil Measurement

In this series of tests in-water oil concentrations were estimated in 3 or 4 different ways depending on the test. A Turner 10AU flow-through fluorometer, a LISST 100 particle size analyzer and a Turner Designs TD500D oil-in-water analyzer were used in all tests and a Wet Labs *in-situ* fluorometer (aka Bubba Buster) was used in a number of the early test runs. The Wet Labs fluorometer and an operator were provided by OSRL for the first week of the test program for equipment and operator training purposes. The LISST 100 device, the Bubba Buster and the pump feeding the 10AU were all positioned at 1.5 meters below the calm water level. Water samples were taken from the Turner 10AU water stream for subsequent extraction and analysis using the Turner Design, TD500D, hand held fluorometric hydrocarbon analyzer. Technical details for these four oil-in-water measuring systems can be found at the following web sites.

LISST 100 : www.sequoiasci.com
Turner Products: www.oilinwatermonitors.com
Wet Labs: www.wetlabs.com

Dispersed oil drop size distributions were measured using the LISST 100 particle size analyzer. This device also generates an estimate of oil concentration based on the oil drop information gathered. The oil-in-water concentration estimates from the 4 devices are compared in the results section of the report.

2.3 Test Procedure

The basic test procedure used for all dispersant effectiveness tests is as follows.

1. The oil containment area is established in the Ohmsett tank by placing a single boom across the south end and a double boom barrier at the north end.
2. The oil and dispersant are loaded into their respective supply tanks on the main bridge deck.
3. The main bridge is positioned at the southern quarter point within the boomed area.
4. The wave paddle is started and the waves are allowed to develop to a stage just prior to the formation of breaking waves. A three and one-half inch stroke and 34 to 35 strokes per minute wave paddle setting was used in all of these tests.
5. The bridge is moved south at the required speed (between 0.25 and 1 knots) to achieve the required slick thickness and dispersant application dosage.
6. As the bridge is moving, the oil is pumped at the required rate (20 gpm is usual flow rate) onto the surface through the discharge manifold mounted on the south side of the bridge.
7. As the oil is layed down, the dispersant is applied onto the oil slick from the spray bar system mounted on the north side of the bridge in the same pass as the oil discharge.
8. Each test is video taped for future visual reference.
9. The waves are left on for 30 minutes after which the wave paddle is stopped.
10. Two or three passes are made down the tank during the 30 minute mixing period with instrumentation towed through the water to measure oil concentration and oil drop sizes.
11. Tank turbulence measurements are made using a Sontek Acoustic Doppler Velocimeter with the bridge stationary prior to each instrument pass.

12. After the wave paddle is stopped and the tank surface has quieted down water spray from the bridge fire monitors is used to carefully sweep any surface oil remaining on the water surface at the end of the test to a common collection area at one corner of the containment boom.
13. The oil is then removed from the water surface using a double-diaphragm pump and suction wand and placed in a collection drum. If only very small quantities of oil remain at the end of a test it is collected using a long-handled ladle and placed in a five-gallon bucket.
14. A small quantity of emulsion breaker is thoroughly mixed into the contents of the drum or bucket and they are allowed to stand overnight. The free water present is decanted from drums as in Figure 6. Water is decanted from the five-gallon buckets by drilling a small diameter hole in the bottom of the bucket and allowing any free water to drain away from the floating oil.

Figure 6. Drum Decanting Method. (Air inlet tube to bottom of drum is placed in drum bung. Water is decanted from drum vent when drum is inverted.)

15. The remaining oil and water are well mixed and a sample is taken for water content and physical property determination.
16. The quantity of liquid in the drum is measured and then adjusted by subtracting the amount of water in the oil as determined by a water content analysis.
17. The amount of oil dispersed is reported as the volume of oil discharged minus the amount collected from the surface all divided by the amount discharged.
18. Dispersant effectiveness is calculated after adjustment for natural dispersion and evaporative loss.

3.0 Oils and Dispersant Used in Test Program

Four Alaskan crude oils were used in the current test program. They were Alaskan North Slope (ANS), Endicott (End), Pt. McIntyre (PtMc), and Northstar (NS) and crude oils. ANS is a blend of crude oils from the various Alaska North Slope fields, whereas the other oils are specific to their production areas. Oils were tested fresh, weathered by removal of light ends using air sparging, weathered by placing the oils on the tank in breaking wave conditions (high-energy 33 cpm waves) and non-breaking waves (low-energy 28 cpm waves) long enough for the oil to reach a volume percent loss similar to the air sparged oils. The on-tank weathered oils were weathered on the tank and then collected and stored in drums at 0ºC until used in a test. The oils were weathered, collected and then re-released using the oil discharge header to facility the control of the dispersant dosage and to ensure that a similar test method was used in all tests.

Corexit 9527 dispersant was used in all tests where dispersant was applied as it is the only dispersant stockpiled in Alaska for spill response.

Air sparging is a standard procedure to weather crude oils that is used by researchers worldwide. In this test program sparging was accomplished by attaching an air hose to a perforated pipe that was submerged in the oil through the bung of the drum of oil to be weathered. An exhaust line was fitted to the drum's vent hole and routed to the outdoors. Compressed air was then pumped through the air hose into the oil and allowed to escape through the vent hose. A drum band heater was used to heat the oil to speed the evaporation process. The weight of the oil was recorded prior to the start of the weathering and checked periodically to establish the status of the weathering. The target evaporative loss for the oils used was 12% by mass for the ANS and Pt. McIntrye oils, 30% for the Northstar and 10% for the Endicott oil to match the conditions used in the 2003 testing.

One objective of the study was to compare the process of on tank weathering (light-end losses only without significant water-in-oil emulsion formation) to that of air sparged weathering. The goal was not to generate water-in-oil emulsions in the on-tank weathering but to match the light-end loss achieved in the air sparging process as close as possible. The physical properties of the oils used in the dispersant tests are shown in Table 1. The densities of the fresh and air-sparged oils used in the 2003 test series are also provided in Table 1 for comparison. Three of the fresh oils (ANS, NS and Pt.Mc.) used in the 2006 testing were lighter than they were when tested in 2003.

The Endicott oil was not subjected to on-tank weathering due to time constraints. The Pt. McIntyre oil was the first to be weathered and the high-energy weathering was extended for too long a period and a viscous water-in-oil emulsion formed. The volume percent loss for this high-energy on-tank weathering was also considerably higher than the volume percent loss in the air sparged case (27.6% versus 12.4%). The low-energy weathering of the Pt. McIntyre oil was similar to the air sparged (15.9% versus 12.5%). The on-tank weathered ANS crude oils had losses about 10% higher than the air sparged oil (25.1% and 26.5% versus 15%). The Northstar on-tank weathered oils had similar losses when compared to the air sparged oil (37.6% and 38.6% versus 34.5%). In all cases the on-tank weathering resulted in higher evaporative losses than achieved by air sparging. The on-tank weathered oils also formed water-in-oil emulsions of varying water contents and stabilities. Although this was not intended it was inevitable. The water contents of these oils at the time they were used in the dispersant application testing are shown in Table 1.

Table1. Physical Properties of Test Oils

Oil	2003 Test Oils	2006 Test Oils					
	Density (mg/l) 25 ºC	Density (mg/l)	Viscosity (cP) $100s^{-1}$, 1ºC	Oil Loss (% Volume)	Oil Loss (% Weight)	Wave Duration (min)	Water Content (%)
Alaska North Slope							
Fresh	0.873	0.863	22	0	0	-	0
Air sparged	0.912	0.887	93	15.3	12.7	-	0.2
On-Tank Lo-Energy		0.901	203	25.1	na[1]	66	5
On-Tank Hi-Energy		0.903	200	26.5	na	49	16
Endicott							
Fresh	0.878	0.9018	270	0	0	-	0.2
Air sparged	0.914	0.917	644	20.1	18.6	-	0
Northstar							
Fresh	0.812	0.8025	7.6	0	0	-	0
Air sparged	0.864	0.839	36	34.5	30.5	-	0
On-Tank Lo-Energy		0.842	116	37.6	na	80	40
On-Tank Hi-Energy		0.843	143	38.6	na	37	48
Pt. McIntyre							
Fresh	0.890	0.861	34	0	0	-	2
Air sparged	0.902	0.880	76	12.5	10.6	-	0.5
On-Tank Lo-Energy		0.884	214	15.9	na	65	45
On-Tank Hi-Energy		0.898	695	27.6	na	156	48

[1]not analyzed

In each weathering session the oil was discharged at the wave paddle end of the tank, the waves were started and the oil moved north under the influence of the waves and winds. The waves were generated using a 3.5-inch paddle stroke and paddle frequencies of 28 cpm for the low-energy non-breaking wave weathering and 33 cpm for the high-energy breaking wave weathering. The waves were shut down prior to the oil reaching the north containment boom. The oil was then swept back to the south end of the tank in calm water using the auxiliary bridge’s containment boom and the waves restarted. This process was then repeated until the target degree of weathering was achieved. The wave duration time in Table 1 identifies the total actual time that waves were on during each weathering session. At the end of the weathering process the oil was collected from the tank surface using a double-diaphragm pump and suction tube and placed in drums stored at 0ºC for later use. Any free water collected during the recovery of the oil was decanted from the drums prior to final testing. All oils were stored in a refrigerated storage container set at 0ºC to ensure that they were as close to ambient water temperature as possible during the testing. The volume percent loss data in Table 1 were determined by measuring the collected oil density and comparing this to a percent loss versus density curve developed using tray evaporation data for each of the oils. The tray evaporation data collected for the oils are provided in Appendix A.

3.1 Test Matrix Completed

A total of 10 control (no dispersant applied) and 15 Corexit 9527 dispersant applied tests were completed in the test program that was conducted over a three week period in late February and early March of 2006. A summary of the tests completed and their test numbers is provided in Table 2.

Table 2. Test Matrix

Oil	Control Test Number	Dispersant Applied Test Number
Alaska North Slope		
Fresh	2	3
Air sparged	5	6
On-Tank Lo-Energy		10
On-Tank Hi-Energy		9
On-Tank Hi-Lo Mix		23
Endicott		
Fresh	8	17
Air sparged	7	11, 25
Northstar		
Fresh	13	14
Air sparged		15
On-Tank Lo-Energy	12	
On-Tank Hi-Energy	18	16
Pt. McIntyre		
Fresh	1	20
Air sparged	4	21
On-Tank Lo-Energy		24
On-Tank Hi-Energy	22	19

4.0 Test Results

4.1 Test Conditions and Dispersant Effectiveness Estimates

The test conditions and estimated Dispersant Effectiveness (DE) for all of the large-scale tank tests are summarized in Table 3. The test results are grouped based on oil type (column 1 in Table 3) rather than the order of test completion. The viscosities of the initial oils are provided in column 2 and the water contents of the test oils prior to discharge for dispersant testing are in column 3. The oil viscosities tested ranged from a low of 7.6 cP for fresh Northstar crude to 695 cP for the high-energy, on-tank weathered Pt. McIntyre oil. These viscosities were measured at 1.25 °C and a shear rate of 100 s^{-1}. The water contents of the fresh and air sparged oils were very low (0 to 2%). The water contents of the on-tank weathered oils were 5 to 16% for ANS crude and between 40 and 55% for the Northstar and Pt. McIntyre oils.

Air, water, oil and dispersant temperatures just prior to each test are provided in columns 4 through 7. The oil and water temperatures during the test program were within a few degrees of 0° C with the exception of test #21 and test #25 where the oil naturally warmed to about 5 and 10° C, respectively, prior to discharge.

The quantity of oil applied in each test is reported in column 8. Sixty-five to seventy-five liters of oil was discharged in most of the tests. In a few cases, where a limited amount of oil was available, smaller volumes of oil were spilled. The estimated oil thickness during oil discharge at the point where the dispersant spray contacted the oil is shown in column 9. Estimated oil slick thickness ranged from 0.9 to 3.8 mm.

Table 3. Ohmsett Tank Dispersant Effectiveness (DE) Test Results Summary

Oil	Initial Oil Viscosity (cP)	Initial Oil Water Content (%)	Air Temp °C	Water Temp °C	Oil Temp °C	Dispersant Temp °C	Oil Volume (liters)	Oil Thickness (mm)	DOR	% Collected	% Evaporated	% Dispersed / Lost	DE (Control Adjusted)	Links to Video Segments	Test #
Alaska North Slope															
Fresh	22	0	-2.7	-2	7.8	-	74.8	0.9	Control	60.3	19.3	20.4	-	467 Test 2.mpg	2
Fresh	22	0	1.2	0.3	-1.7	3.9	75.7	1.2	38	5.3	-	94.7	74.3	467 Test 3.mpg	3
Air sparged	93	0.2	3.3	-0.6	-0.6	-	75.9	1.1	Control	77.9	9.6	12.6	-	467 Test 5.mpg	5
Air sparged	93	0.2	6.2	0.0	2.2	5.0	50.4	1.1	26	2.7	-	97.3	84.7	467 Test 6.mpg	6
On-Tank Lo-Energy	203	5	-1.9	0.0	-4.4	-1.7	69.7	2.8	28	2.6	-	97.4	84.8	467 Test 10.mpg	10
On-Tank Hi-Energy	200	16	0.5	0.0	-0.6	3.3	62.8	2.6	25	3.4	-	96.6	84.0	467 Test 9.mpg	9
On-Tank Hi-Lo Mix	256	14	8.6	2.8	3.3	7.2	65.2	1.2	21	1.1	-	98.9	86.3	467 Test 23.mpg	23
Endicott															
Fresh	270	0.2	0.5	0.0	0.0	-	72.5	1.2	Control	61.8	24.7	13.5	-	467 Test 8.mpg	8
Fresh	245	0.2	7.1	2.8	3.3	7.2	79.8	3.3	27	0.4	-	99.6	86.1	467 Test 17.mpg	17
Air sparged	772	0	-0.7	0.0	-1.1	-	73.4	3.2	Control	71.5	5.7	22.8	-	467 Test 7.mpg	7
Air sparged	644	0	-0.1	0.0	-2.8	0.0	73.4	3.8	40	14.9	-	85.1	62.3	467 Test 11.mpg	11
Air sparged	644	0	15.7	3.3	10.6	13.9	77.0	2.5	17	8.9	-	91.1	68.3	467 Test 25.mpg	25
Northstar															
Fresh	7.6	0	5.6	1.7	0.0	-	80.2	1.6	Control	31.9	45.0	23.1	-	467 Test 13.mpg	13
Fresh	7.6	0	7.3	1.7	2.2	9.4	69.4	1.5	25	3.7	-	96.3	73.2	467 Test 14.mpg	14
Air sparged	36	0	7.3	1.9	-1.7	0.6	75.7	3.2	43	8.9	-	91.1	68.0	467 Test 15.mpg	15
On-Tank Lo-Energy	116	40	2.8	1.1	-1.7	-	47.9	1.9	Control	49.4	12.3	38.3	-	467 Test 12.mpg	12
On-Tank Hi-Energy	143	48	1.6	-2.8	-2.8	-	39.9	1.7	Control	24.2	17.2	58.6	-	467 Test 18.mpg	18
On-Tank Hi-Energy	143	48	5.6	2.2	0.0	1.7	38.3	2.4	23	1.7	-	98.3	39.7	467 Test16.mpg	16
Pt. McIntyre															
Fresh	34	2	-2.0	0.0	7.8	-	66.4	2.2	Control	76.3	12.2	11.5	-	467 Test 1.mpg	1
Fresh	34	2	7.6	3.3	5.0	11.7	68.4	1.1	18	0.7	-	99.3	87.8	467 Test 21.mpg	21
Air sparged	76	0.5	0.6	-0.4	-0.6	-	75.3	1.1	Control	68.4	9.4	22.2	-	467 Test 4.mpg	4
Air sparged	76	0.5	5.8	2.8	2.2	8.3	67.8	2.1	18	0.7	-	99.3	77.1	467 Test 20.mpg	20
On-Tank Lo-Energy	214	55	13.7	2.8	2.8	16.7	33.6	1.9	28	1.0	-	99.0	76.8	467 Test 24.mpg	24
On-Tank Hi-Energy	695	48	7.8	2.8	2.2	-	28.0	0.9	Control	19.6	3.8	76.7	-	467 Test 22.mpg	22
On-Tank Hi-Energy	695	48	3.9	2.8	0.6	4.4	39.7	3.5	25	5.9	-	94.1	71.9	467 Test 19.mpg	19

Note: DE is the dispersant effectiveness estimate after accounting for oil lost in the control run.

The target dispersant-to-oil (DOR) ratio for all tests was 1:20. Due to oil spreading differences this was not always achieved. DOR's ranged from as high as 1:17 to as low as 1:43. The effectiveness of the dispersant did not appear to be significantly different over this range of DOR as evidenced by the results for tests 11 and 25 on the air sparged Endicott crude. These tests had 1:40 and 1:17 DORs, respectively, yet the final dispersant effectiveness was only slightly less (6%) for the 1:40 application. All of the other low-dose tests achieved DE values similar to the high-dose tests.

The "% collected" data in Table 3 is the volume percentage of the oil spilled (after accounting for water contents in both the discharged and collected oils) that was collected from the surface after each test.

The percentage of oil evaporated over the duration of the test was determined only for the control runs. This value was determined based on the densities of the discharged and collected oils and the density/volume loss relationships shown in Appendix A. In the dispersant applied tests the oil dispersed within a few minutes of spraying so little time was available for oil evaporation. Use of the collected oil density to determine the percent of oil evaporation would not be valid in these cases since most of the oil dispersed before evaporation could occur.

The "% Dispersed/Lost" data are the percentages of oil not accounted for by collection or evaporation estimates. This oil not accounted for directly could be on the tank side-walls or end booms (although these surfaces are swept by the fire monitors during the collection of the oil at the end of each test) or dispersed or dissolved into the water column. In "successful" dispersant applied cases the oil has less of an opportunity to evaporate or adhere to side-walls or booms as the oil is seen to quickly disperse into the water and so these losses can more confidently attributed to dispersion of oil. In the "dispersant applied" tests the "% Dispersed / Lost" estimates were all very high. There were ten tests with 95% or higher values, four tests with 90% or higher and one test at 85%, with this being the lowest value. The valid control runs resulted in "Losses" ranging from 11.5% for the fresh Pt. McIntyre to as high as 59% for the Northstar on-tank high energy emulsion. With the exception of two valid control runs with the light Northstar oil the “% Dispersed / Lost” values were in the 10 to 20% range meaning that 80 to 90% of the spilled oil was accounted for by either oil collection or evaporation estimates. The high oil losses for the Northstar control runs can be attributed to natural dispersion/dissolution of this very light oil.

The dispersant effectiveness (DE) “control adjusted” data column is the “% Dispersed / Lost” estimate for each dispersant applied run minus the “% Dispersed / Lost” estimate for the control run using the same oil. This number can be regarded as the minimal incremental benefit (dispersion) achieved through the application of chemical dispersant to the oil slick after the control test results are taken into account. The calculated DE values should be viewed as the minimal benefit derived from the use of dispersants in these tests. The actual dispersant effectiveness could easily be as high as the %D/L results reported for those tests where immediate and complete dispersion of the oil occurs before any oil has the opportunity to reach the tank side walls or end booms or evaporate. The data collected for the control test for the Pt. McIntyre on-tank, high-energy weathered oil (test #22) is suspect. The oil discharge header was partially clogged in this test and the emulsion sprayed out onto the tank under higher pressures than normal and spread to an uncharacteristically uniform and thin oil slick. The total volume of liquid spilled was the lowest of all tests and the small amount of oil collected at the end of the test indicated that over 75% of the liquid released was not collected. This was the most viscous oil tested yet the control run resulted in more “lost” oil than all of the other control tests. It is speculated that the liquid released in this control test had a higher proportion of water than was recorded and therefore a poor oil recovery was estimated. For this reason the control run data for test 4 (air sparged Pt. McIntyre) has been applied to test 19 to determine the final DE value shown in Table 3. The DE (control adjusted) values for the dispersant applied runs indicate that the application of dispersant improved the dispersion of the oils in all but one test cases by 60% or more with most tests achieving an improvement greater than 75%.

Hypertext links are provided in Table 3 to composite video clip segments of each of the tests. The video records can be viewed by double-clicking on a link when accessing this document through MS Word or Adobe Acrobat. The video record for each test includes short video segments that have been merged together into one file to show the progression of the test from the beginning to the end. The video clips provide a good record of the behavior of the oil in each of the tests and it is highly recommended that they be viewed to get a full appreciation of the test program.

In summary, the Corexit 9527 dispersant was effective in all of the tests and resulted in very high oil removal in most tests. In all of the chemically treated tests the %Dispersed/Lost estimates exceeded 90%. Control adjusted effectiveness estimates show a slight reduction in the "incremental increase in dispersion due to dispersant application" for the Endicott, Northstar and Pt. McIntyre oil but not for the ANS crude oil. There was no clear difference in the dispersibility of the air sparged versus the on-tank weathered oils.

4.2 Dispersed Oil Concentrations and Drop Size Distributions

Up to four passes were made down the length of the test tank after the oil was discharged to measure in-water oil concentrations and drop size distributions. A LISST 100 particle size analyzer recorded data on oil drop sizes and in-water oil concentrations. A Turner 10AU fluorometer, a Wet Labs *in-situ* fluorometer and water grab samples analyzed using a Turner TD500D were used to measure in-water oil concentrations at a depth of 1.5 meters from the calm water surface. Graphs of the oil drop size distributions and concentrations are provided in Appendix B. Hypertext links to these graphs are provided in Table 4.

Table 4. In-Water Oil Characterization Graph Hypertext Links

Oil	DOR	Links to Oil Characterization Graphs	Test #	% Dispersed/Lost
Alaska North Slope				
Fresh	Control	Test 2	2	20.4
Fresh	38	Test 3	3	94.7
Air sparged	Control	Test 5	5	12.6
Air sparged	26	Test 6	6	97.3
On-Tank Lo-Energy	28	Test 10	10	97.4
On-Tank Hi-Energy	25	Test 9	9	96.6
On-Tank Hi-Lo Mix	21	Test 23	23	98.9
Endicott				
Fresh	Control	Test 8	8	13.5
Fresh	27	Test 17	17	99.6
Air sparged	Control	Test 7	7	22.8
Air sparged	40	Test 11	11	85.1
Air sparged	17	Test 25	25	91.1
Northstar				
Fresh	Control	Test 13	13	23.1
Fresh	25	Test 14	14	96.3
Air sparged	43	Test 15	15	91.1
On-Tank Lo-Energy	Control	Test 12	12	38.3
On-Tank Hi-Energy	Control	Test 18	18	58.6
On-Tank Hi-Energy	23	Test 16	16	98.3
Pt. McIntyre				
Fresh	Control	Test 1	1	11.5
Fresh	18	Test 21	21	99.3
Air sparged	Control	Test 4	4	22.2
Air sparged	18	Test 20	20	99.3
On-Tank Lo-Energy	28	Test 24	24	99.0
On-Tank Hi-Energy	Control	Test 22	22	*76.7*
On-Tank Hi-Energy	25	Test 19	19	94.1

The in-water oil characterization graphs referenced in Table 4 show the following common trends.

When comparing the various methods used to estimate in-water oil concentrations the following trends are evident.

1. The "raw" Turner 10AU flow through fluorometer and LISST 100 gave similar concentration estimates for the ANS and Endicott crude oil tests (see graphs in Table 4 for tests 3, 6 through 10 and 17) tests but gave considerably higher concentration estimates for the Northstar and Pt. McIntyre crude oils (see graphs in Table 4 for tests 13 through 16 20, 21 and 24). This is undoubtedly because the fluorometer's range and sensitivity were set-up using ANS crude oil and the fluorescence of Northstar and Pt McIntyre crude oils are higher than ANS and Endicott.

2. The TD500 results from each test were plotted against the Turner 10AU reading that was recorded when the water grab sample for the TD500 analysis was taken. The linear relationship (best fit curve) between the two data sets was determined to provide a calibration of the Turner 10AU to specific oil types based on the TD500 analyses. When the Turner 10AU output from a test run is adjusted based on this “calibration” the results match those of the TD500 and LISST 100 results for the run very well. This analysis has been completed as an example for test 24 only and the results are presented on the graph in Figure B24.

3. The LISST 100 concentration estimates compared favorably to those of the TD500 results with the exception of those where Pt. McIntyre oil was used. In all of the Pt. McIntyre tests (with the notable exception of test 24) the TD500 concentration estimates are consistently lower than the LISST 100 data. The reason for this discrepancy is unknown.

4. Some effect of dispersed oil drop size on the Turner 10AU readings is evident by comparing the LISST 100 and 10AU outputs for the control runs of the ANS and Endicott tests with their respective spray runs. In the control runs (large oil drops) the 10AU results are somewhat lower than the LISST 100 results but in the spray runs (smaller oil drops) the 10AU results are generally higher. This is likely because a single oil drop-size distribution was used in the calibration of the Turner. The effect of drop size on the 10AU results was less pronounced than expected and appears to be less than the effect of oil type.

5. The Wet Labs fluorometer was available for use in only a sub-set of the tests (tests 4, 5, 7, 8, 9, 10, 11). In tests 4 and 5 the inlet tube to the fluorometer was not parallel to the direction of bridge travel and water did not flow freely past the sensor. As a result, oil fouled the system and a steadily rising fluorescence over the test period was recorded. In the remaining tests, the orientation of the towed device was fixed by adding a tail fin and the sensor remained clean throughout each test. After inspection of the raw fluorescence data collected by the Wet Labs fluorometer we determined that it could be divided by 25 to make it compare favorably to the Turner and LISST 100 concentration data as seen in Figures 7 through 11. This coarse adjustment helps account for the differential in sensitivity between the two instruments. The sensitivity of the Wet Labs fluorometer to oil was considerably higher than that of the Turner 10AU device that was calibrated for the ANS test oil for concentration measurements in the 5 to 400 ppm range.

6. The TD500 fluorometer provided a basis for evaluating the abilities of the LISST 100, Turner 10AU and Wet Labs devices to determine realistic oil-in-water concentrations. The TD500’s range was set using ANS crude oil and calibration curves were established for each oil tested. The LISST 100 concentration output matched that of the TD500 more consistently than the raw insitu-fluorometer results. Because of this and since the LISST 100 is already deployed to establish oil drop size distributions, it is believed that the LISST 100 oil concentration measurements are adequate for any future dispersant effectiveness testing at Ohmsett. The LISST 100

concentration data is easily obtained and provides a reasonable estimate of in-water oil concentration without the need for time-consuming instrument calibration, water sampling, solvent extraction and analysis. The LISST 100 can also be quickly and easily pulled from the water on a regular basis for cleaning of its optical surfaces. It can also be subjected to distilled water blanks and/or concentration and drop size standards in conjunction with the cleaning to ensure that reliable and consistent results are being recorded throughout a test program.

In cases where the oil was chemically dispersed (% Dispersed / Lost greater than 85% in Table 4) the oil concentrations in the water column were elevated significantly (40 ppm to 100+ ppm as per LISST concentration estimates) in the dispersed oil cloud and the oil drop sizes were small (Volume Median Diameters-d50's generally less than 50 microns). In control tests oil concentrations generally remained below 20 ppm (as measured by the LISST) and where elevated oil concentrations were detected the oil drop sizes were much larger than those measured in the dispersant applied runs. A good example of this can be seen by comparing the results of control test 5 with dispersant applied test 6 for air sparged ANS crude. Where concentrations are elevated in the control test (up to 20 ppm) the volume median diameter (VMD) or d50 of the oil drop distribution increases above background to 100 to 150 microns. In test 6, the dispersant applied case, the peak in-water oil concentrations are higher than the control (80 to 100 ppm) and the VMD of the measured drop size distributions drop below that of the background to a value less than 25 microns.

4.3 Wave Turbulence Measurement

A Sontek Horizon ADV velocity probe was deployed at 1.5 meter depth and used to measure X-Y-Z water velocity fluctuations during each test. The probe was set to record 30-second bursts of data at 25 khz frequency. Measurements were made prior to each instrument pass with the bridge stationary. Since allof the dispersant effectiveness and control tests were completed using the same wave paddle settings (3.5-inch stroke and 34 cycles per minute) only one of the data sets captured (Test 11) is provided as an example of the water velocities recorded. This trace is shown in Figure 7. The velocity data from all tests has been processed by first removing single spikes from the records based on a threshold of two standard deviations and then calculating the average kinetic energy (TKE) as determined by the sum of the velocity variances in x, y, and z divided by 2. The TKE value was determined for up to 4 measurements or data collection bursts in each test and these values were then averaged to determine a final representative TKE for each test. These data are provided in Table 5. The average TKE for the test series was 166 with Standard Deviation of 40.

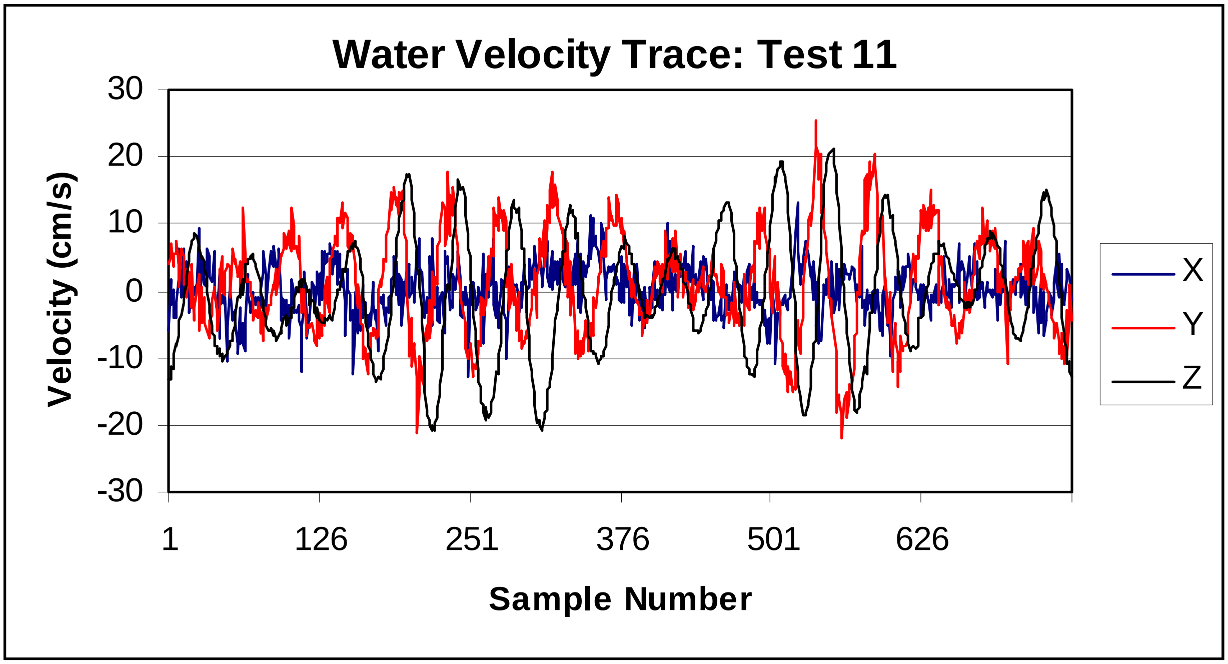

Figure 7. Sample Sontek Horizon ADV Water Velocity Trace

Table 5. Average Kinetic Energy at 1.5 Meter Depth

Test	Burst 1 TKE	Burst 2 TKE	Burst 3 TKE	Burst 4 TKE	Average TKE
1	-	103	-	-	103
2	119	109	-	-	114
3	102	102	93	248	136
4	113	80	136	361	230
5	121	88	84	202	165
6	143	82	174	470	217
7	89	131	150	367	246
8	140	84	109	270	201
9	146	92	48	113	100
11	76	85	111	285	139
12	106	92	102	239	135
13	90	102	87	222	125
14	89	99	134	333	164
15	158	163	168	402	223
16	114	99	120	286	155
17	103	61	101	256	130
19	193	69	84	205	138
20	83	168	82	199	177
21	146	112	128	332	179
22	105	125	101	255	147
23	102	117	178	472	217
24	116	76	145	372	177
25	127	120	177	410	209
				Ave	166
				StdDev	40

5.0 Comparison of Results to 2003 Test Results

As outlined in section 1.0, a series of similar dispersant effectiveness tests were completed in 2003 using the same oils and dispersant (Corexit 9527). Effectiveness tests were also completed on fresh and weathered ANS crude oil using Corexit 9527 in 2002. On-tank weatherings of oil and control tests using air sparged oil were not completed in the 2002 or 2003 test programs so no comparisons can be made for these test conditions. Because evaporative losses were reported in weight percent lost in the 2002 and 2003 tests, weight % losses are used in Table 6. A comparison of the final dispersant effectiveness estimates from the 2003 and 2006 test programs is provided in Table 6 along with one result from the 2002 test series for dispersed fresh ANS which was not tested in the 2003 test program.

Table 6. Comparison of 2003 and 2006 Test Program Results

	2006 Test Results				2003 Test Results			
Oil	Test #	Wt.% Evap	DOR	% Dispersed/Lost	Test #	Wt. % Evap.	DOR	% Dispersed/Lost
Alaska North Slope								
Fresh	2	0	Control	20.4	7 & 44	0	Control	0 & 19.0
Fresh	3	0	38	94.7	9*	0*	31*	98*
Air sparged	6	12.7	26	97.3	1 & 9	17	24 & 25	85 & 86
Endicott								
Fresh	8	0	Control	13.5	6	0	Control	12
Fresh	17	0	27	99.6	8	0	31	74
Air sparged	11	18	40	85.1	14	11	22	3
Air sparged	25	18	17	91.1				
Northstar								
Fresh	13	0	Control	23.1	5	0	Control	0
Fresh	14	0	25	96.3	2	0	18	100
Air sparged	15	30.5	43	91.1	10	29	19	2
Pt. McIntyre								
Fresh	1	0	Control	11.5	13	0	Control	22
Fresh	21	0	18	99.3	12	0	29	77
Air sparged	20	10.6	18	99.3	nd	nd	nd	nd

*- data from 2002 test program

The results for the control tests were very similar for the 2003 and 2006 tests. Between 0% and 20% of the oil spilled was dispersed or lost (D/L) to side walls in all of the control tests in both test programs.

The estimates of non-control corrected dispersant effectiveness (DE) for the fresh oils were also similar in the two test programs. The fresh ANS and Northstar oils were over 90% dispersed in both programs. The fresh Endicott and Pt. McIntyre oils showed less dispersion in the 2003 tests (about 75% DE versus 99% in 2006) but significant dispersion was recorded for these oils in both test programs.

The DE for air sparged ANS was similar in the two test programs (97% in 2006 versus 85% in 2003). The DE estimates for both air sparged Endicott and Northstar were considerably higher in the 2006 testing when compared to the 2003 results (85+% in 2006 compared to 3% in 2003). Oil property differences (higher pour points in the 2003 tests?) due to slightly different weathering conditions or different starting oil properties are a possible explanation for these major differences. The 2006 results suggest that the window of opportunity for dispersant use may be longer than expected based on the previous testing.

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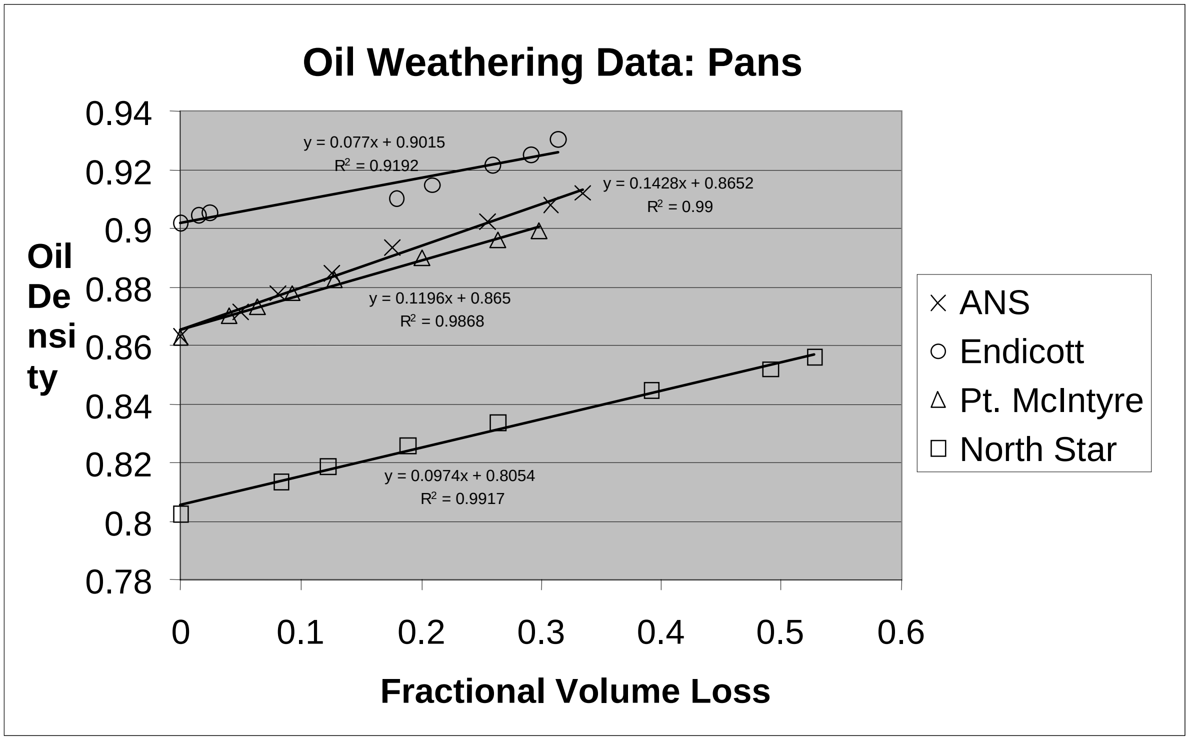
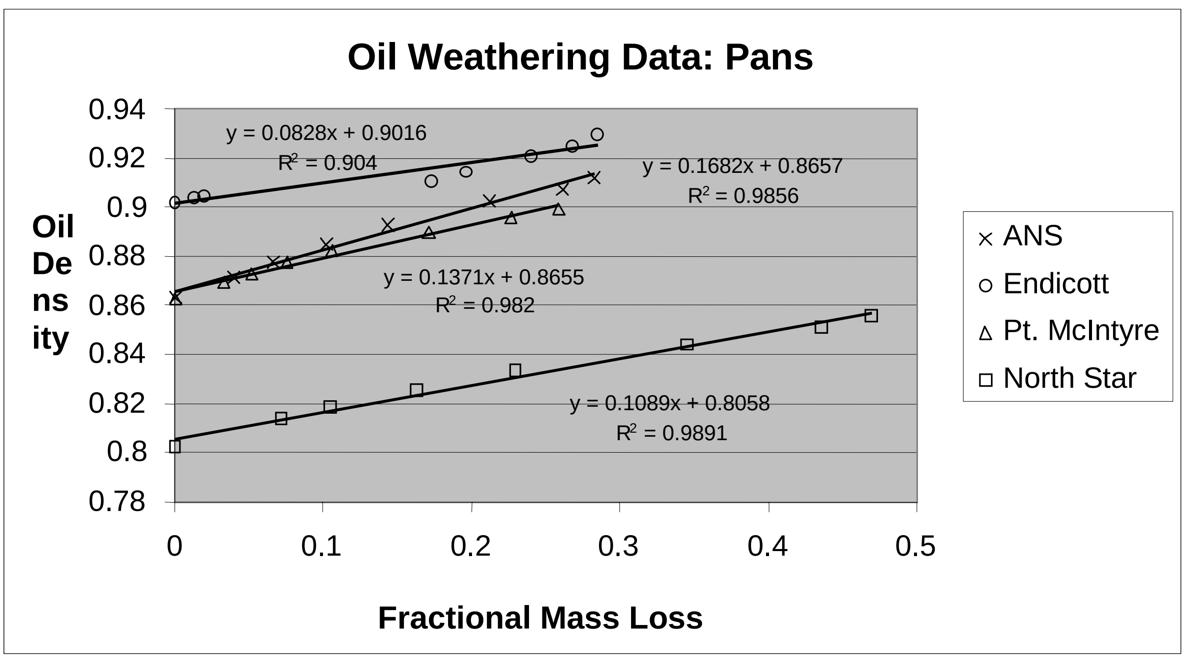
Appendix A. Evaporative Loss Data from Tray Weathering of Oil Samples





Appendix B. In-Water Oil Characterization

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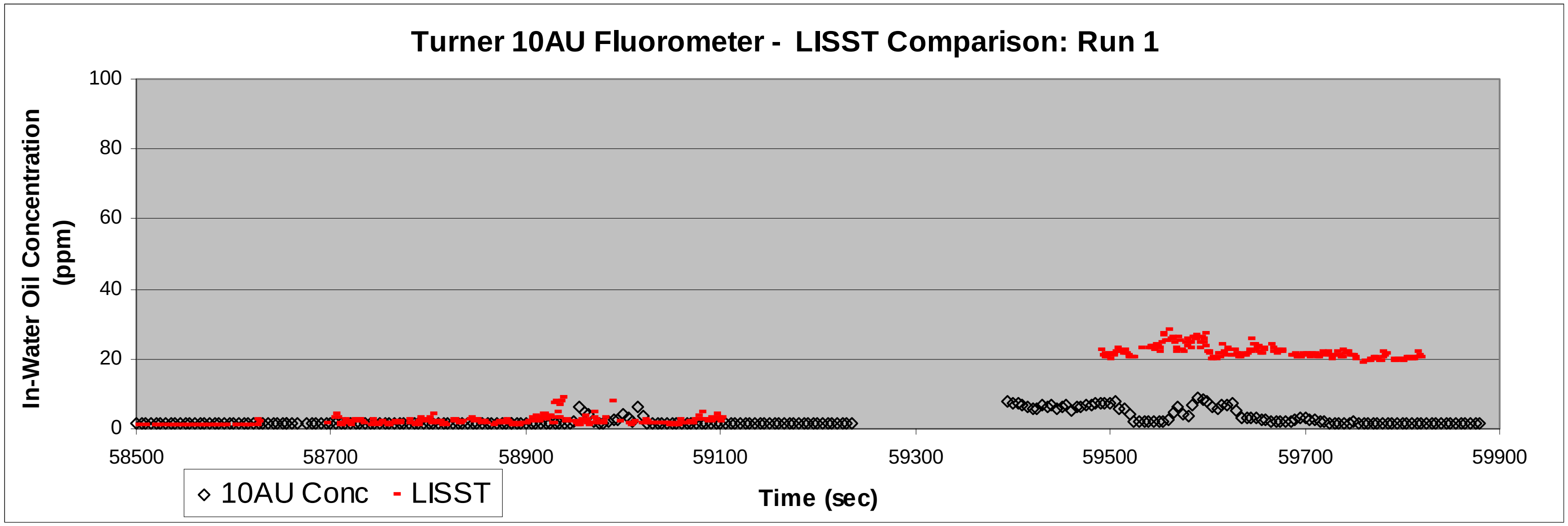

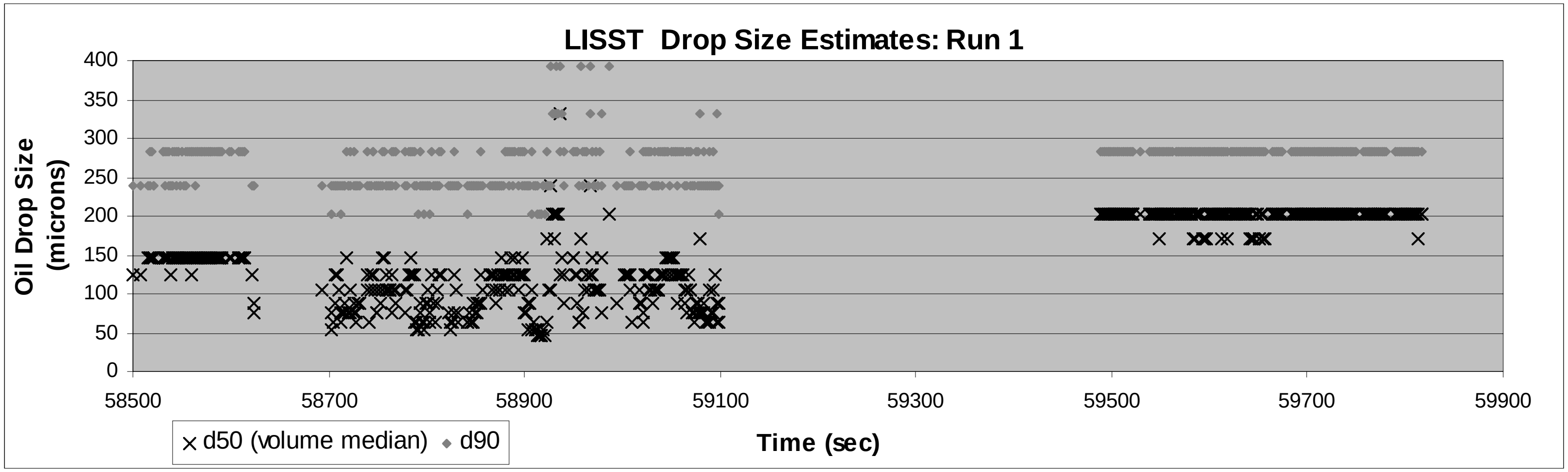

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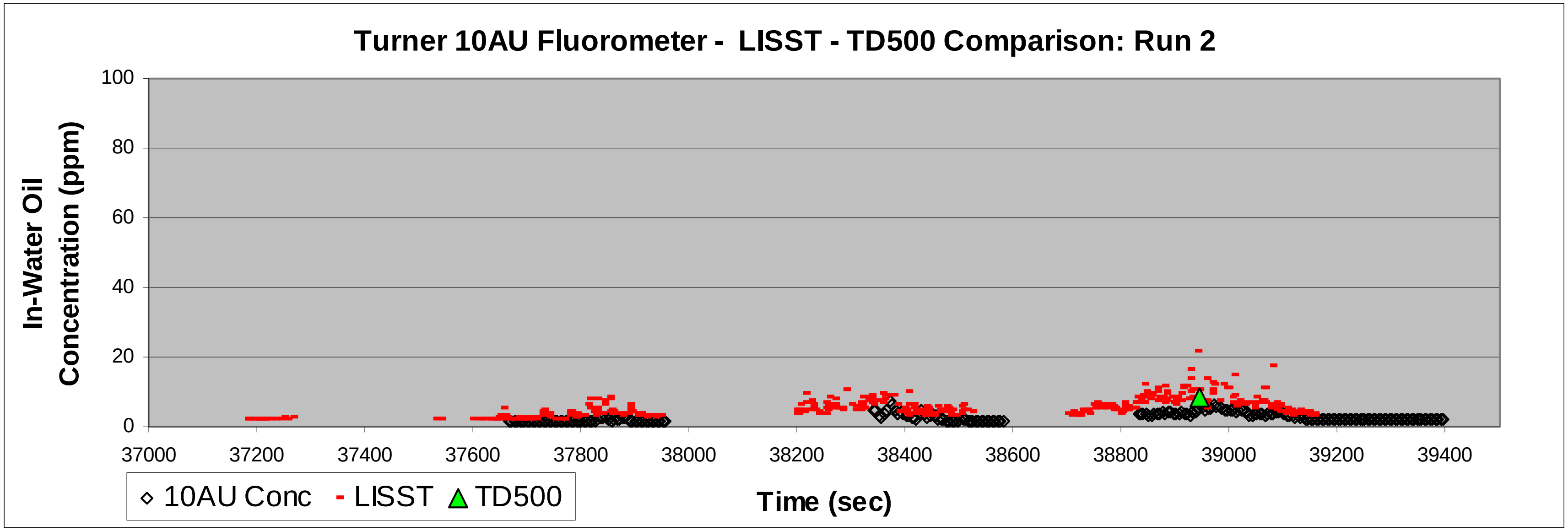

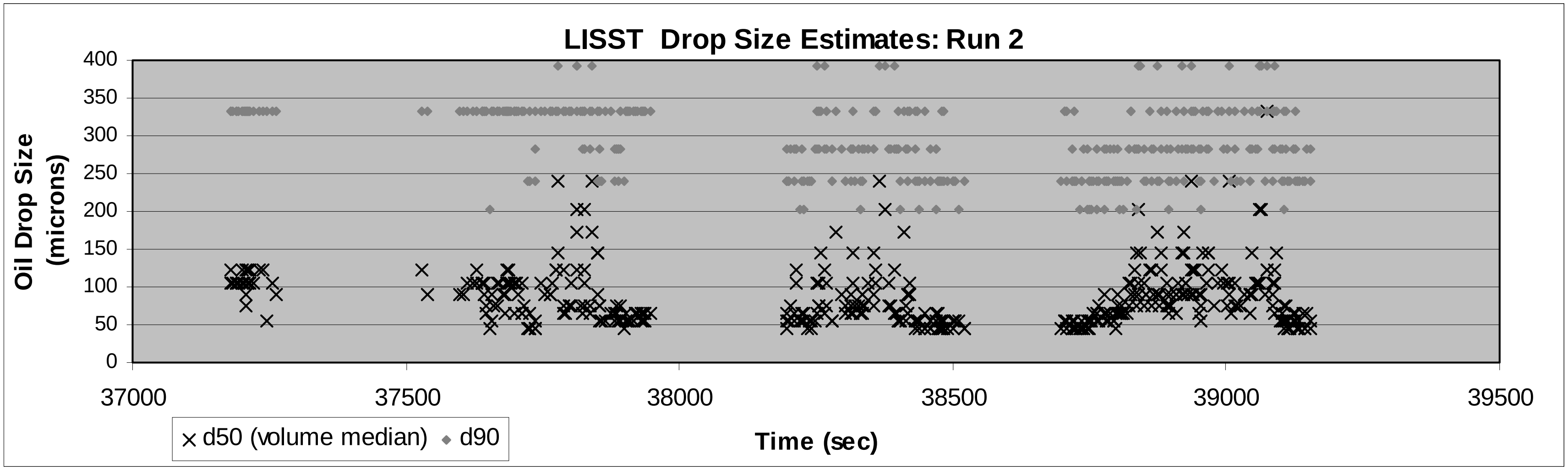

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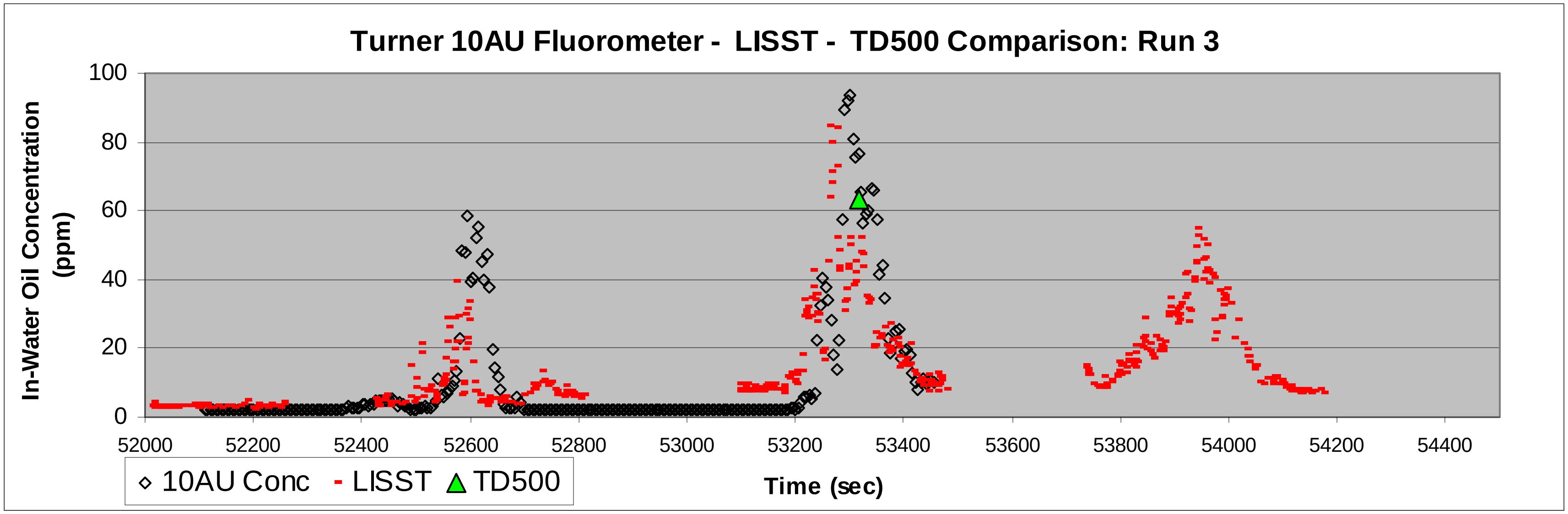

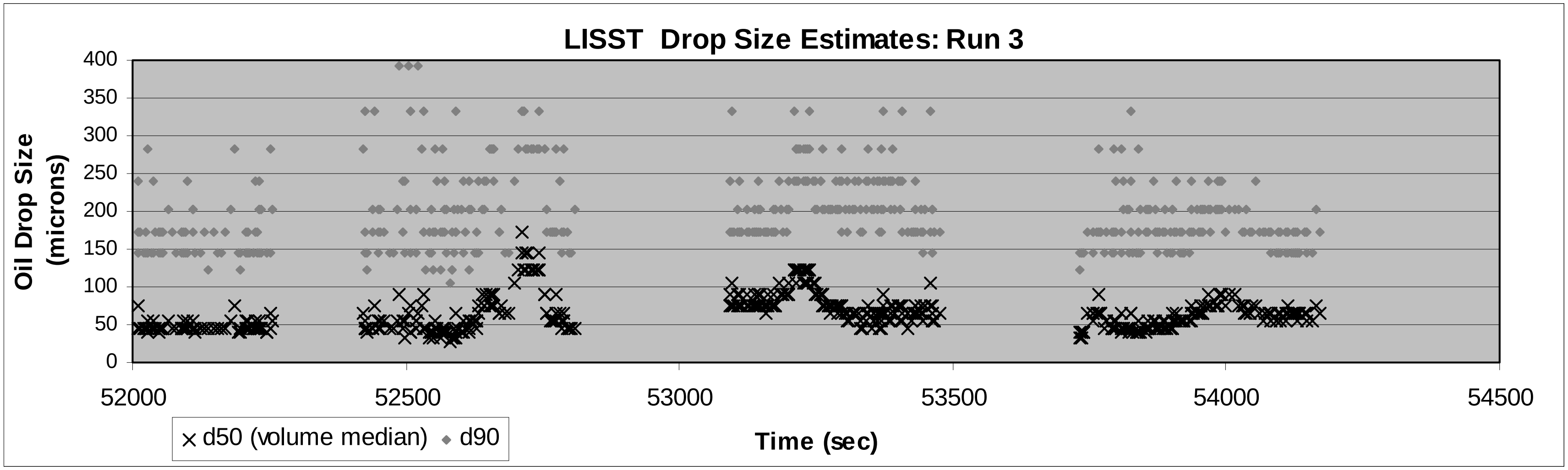

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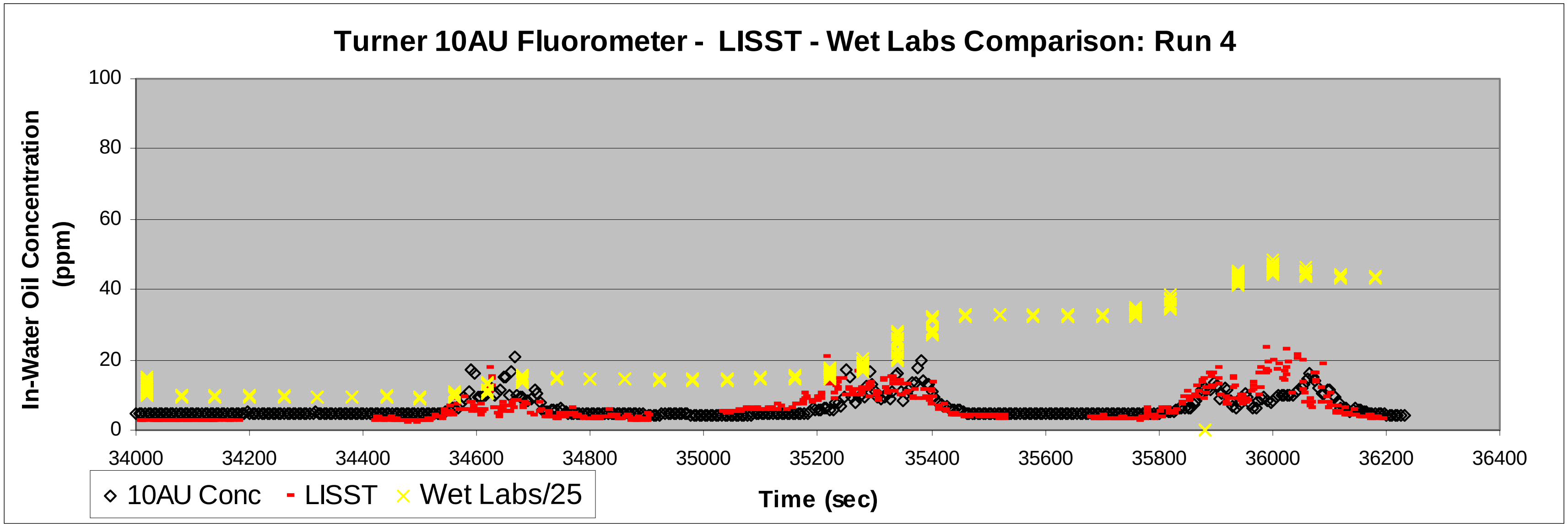

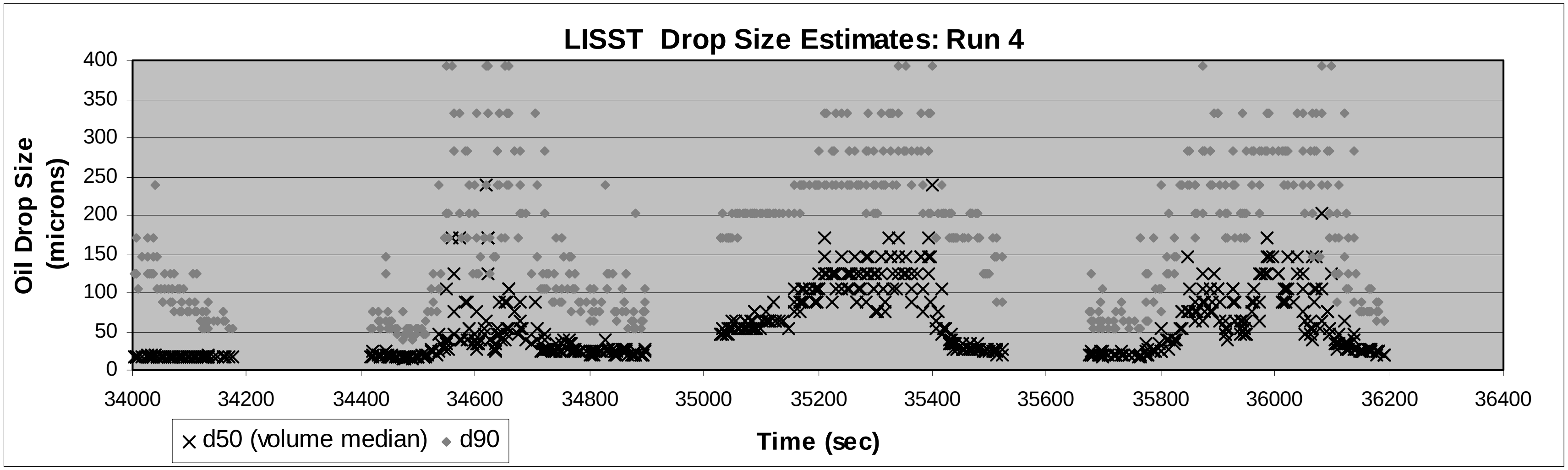

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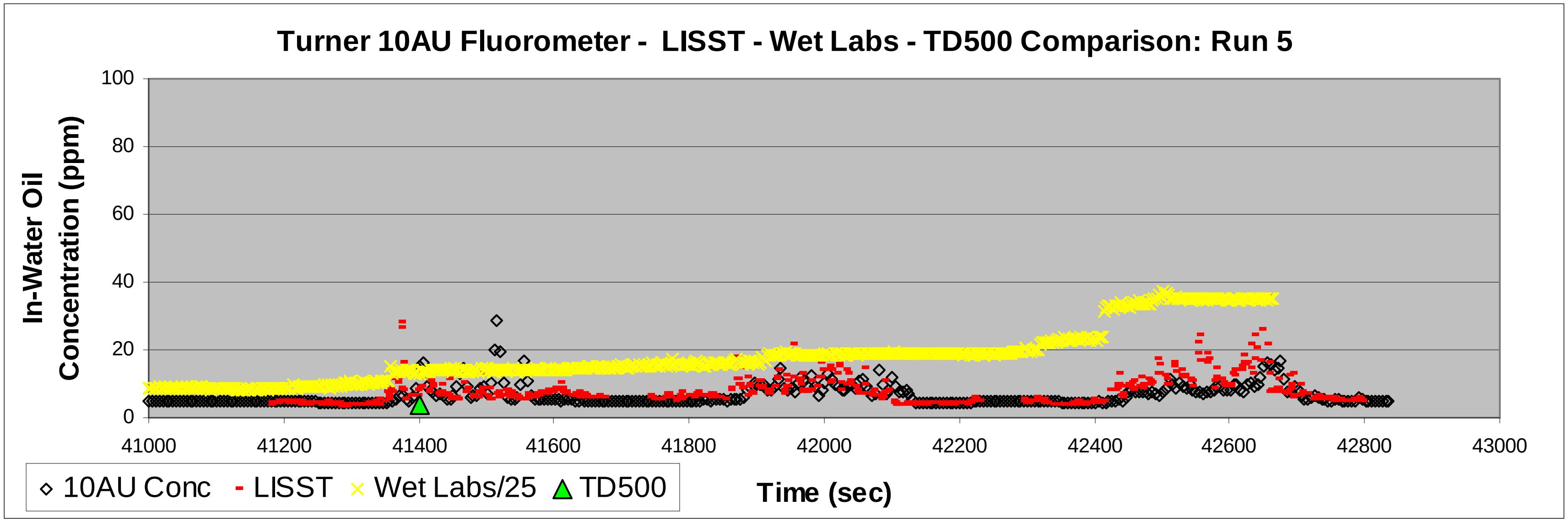

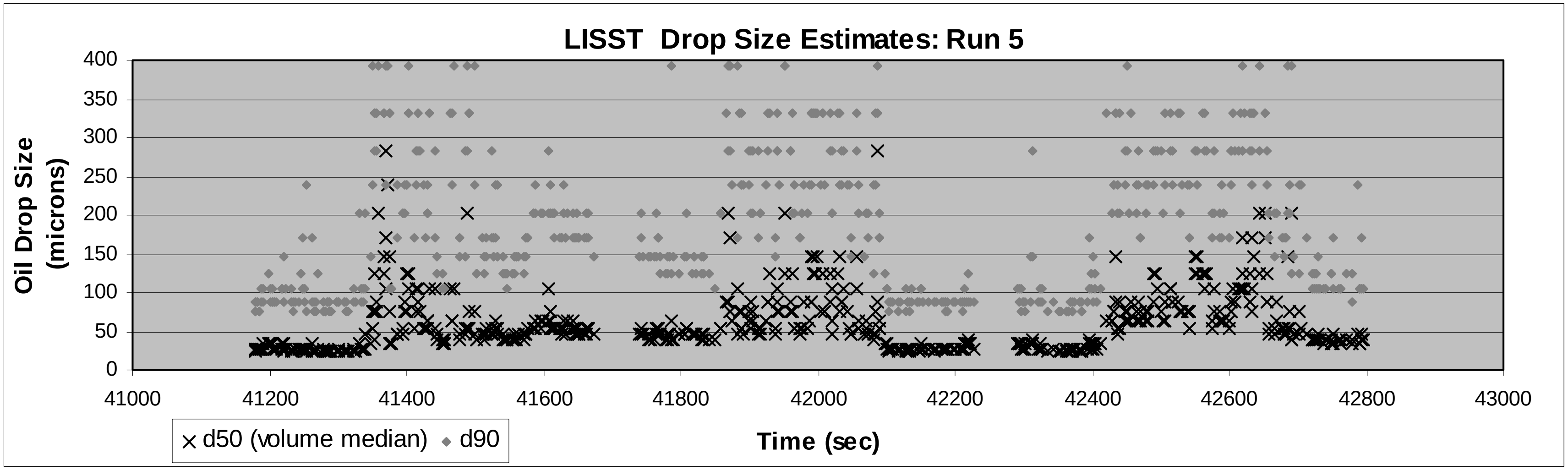

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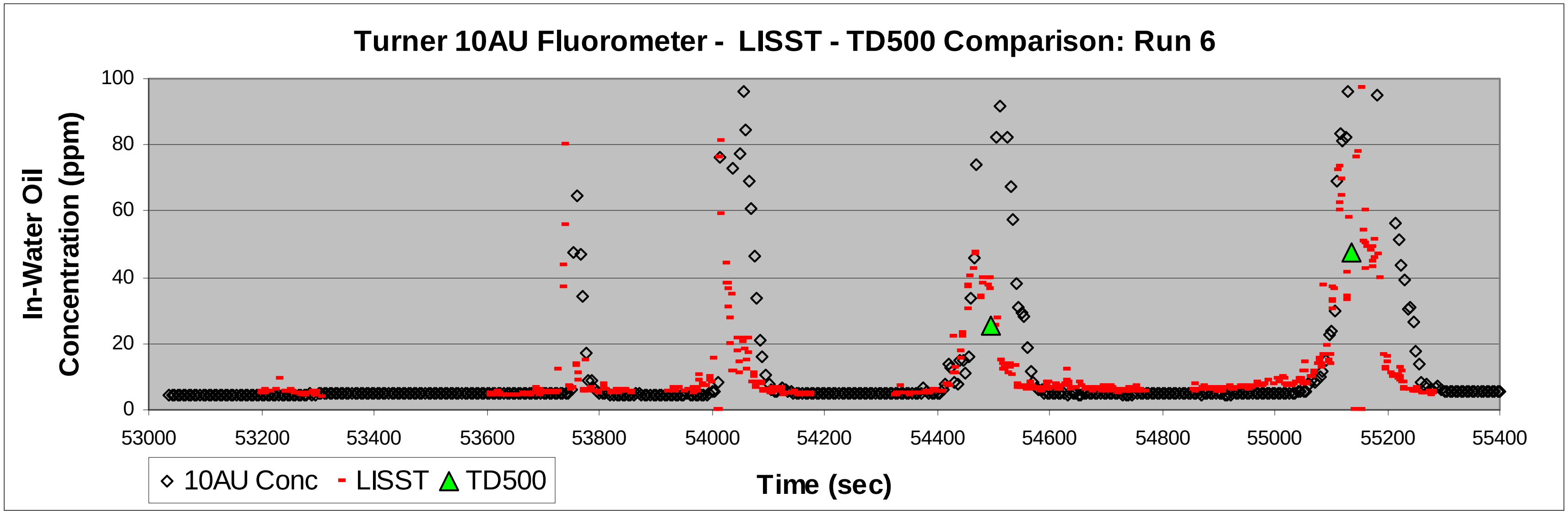

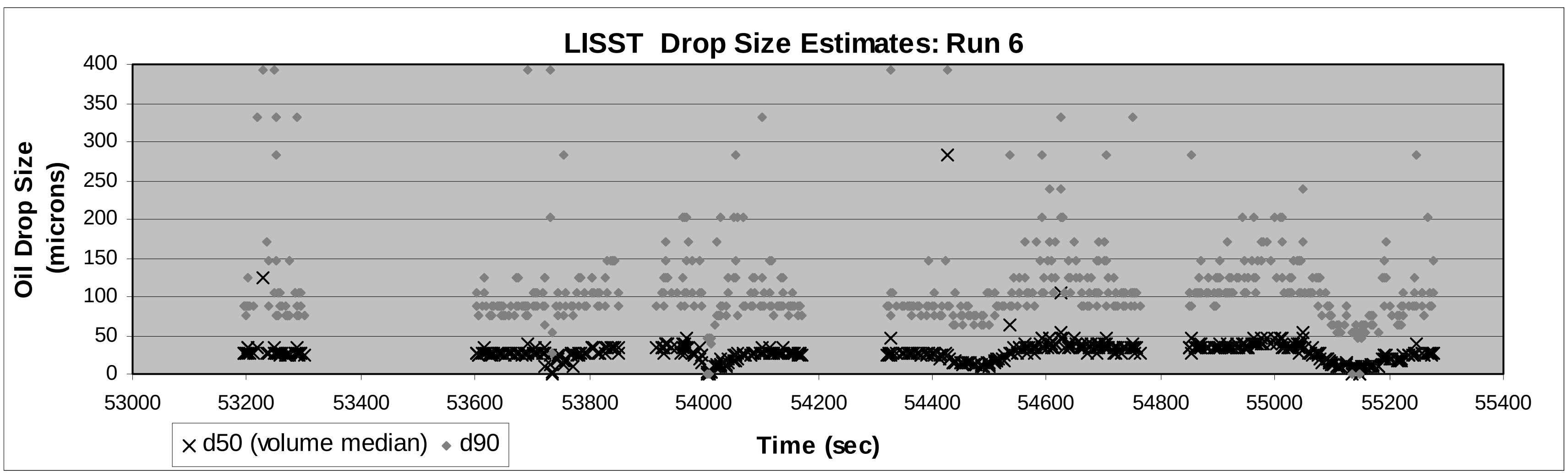

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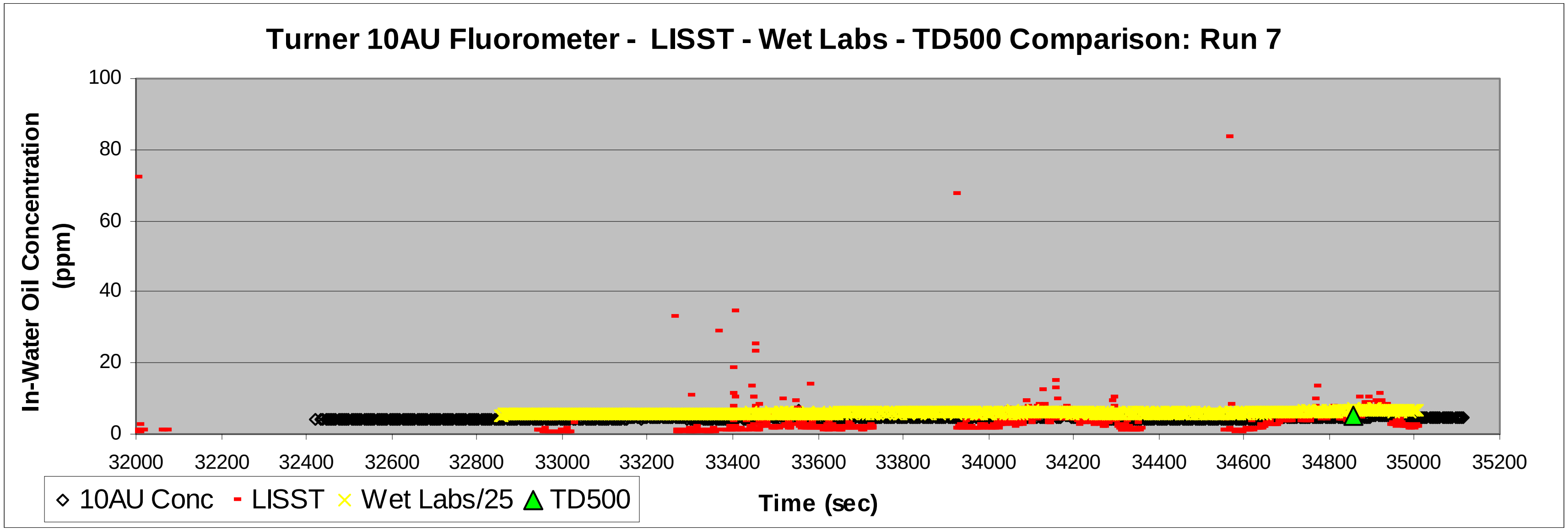

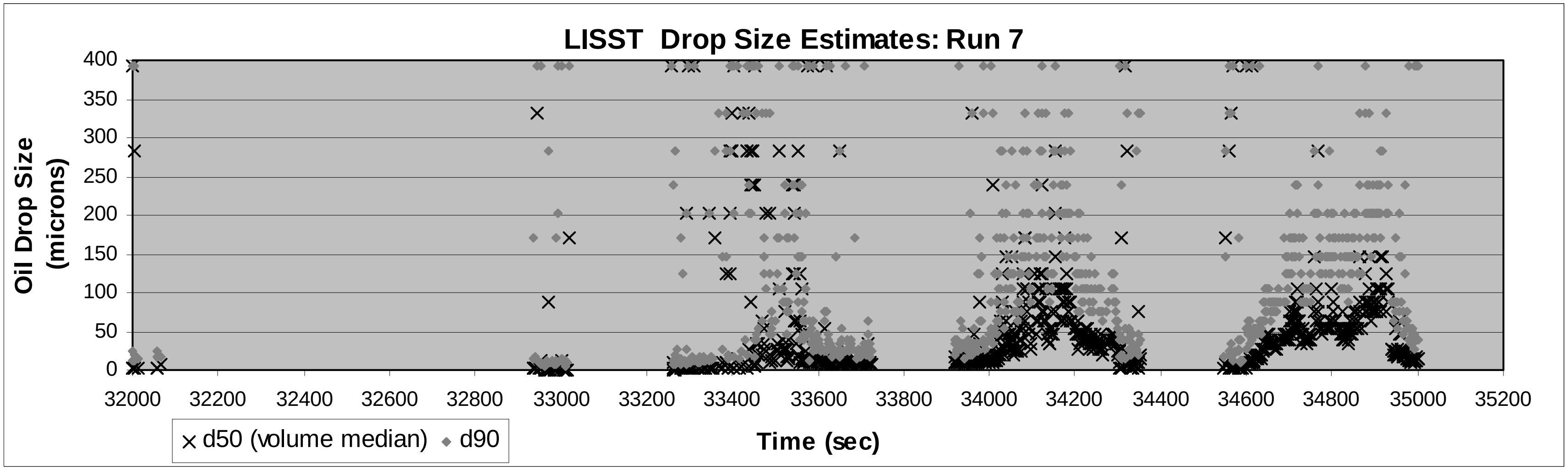

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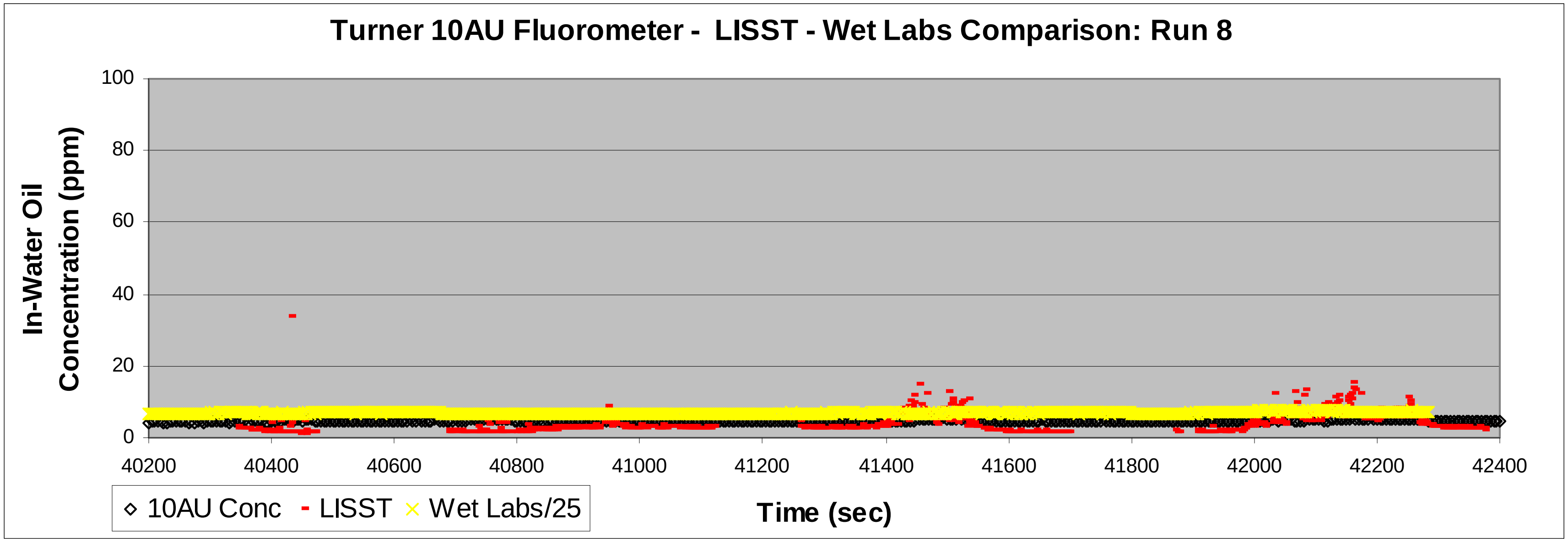

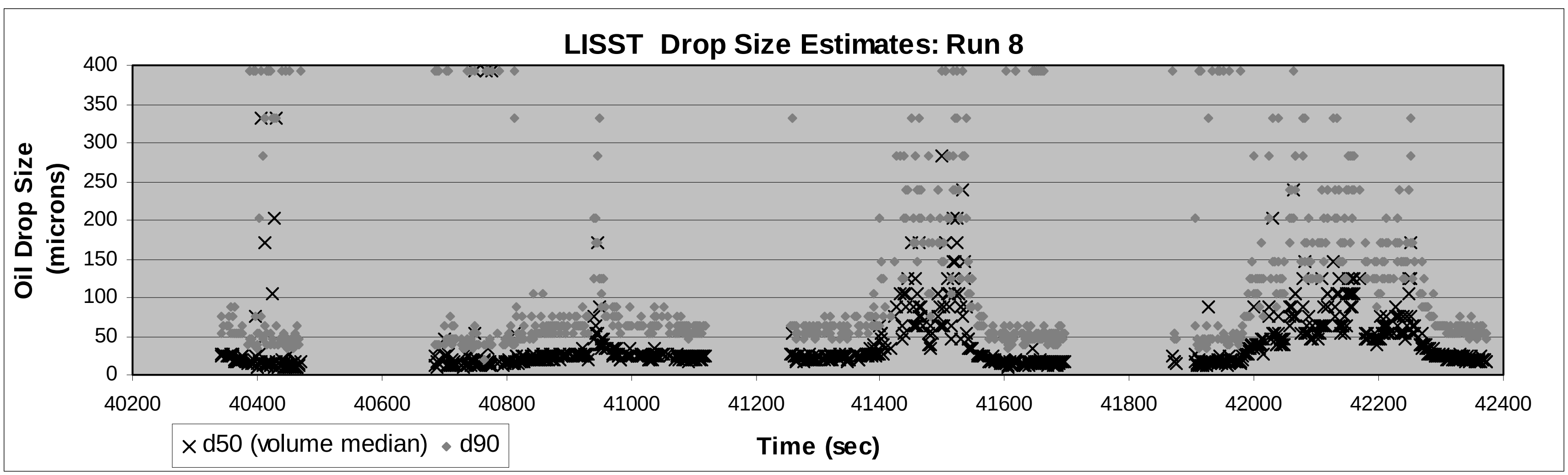

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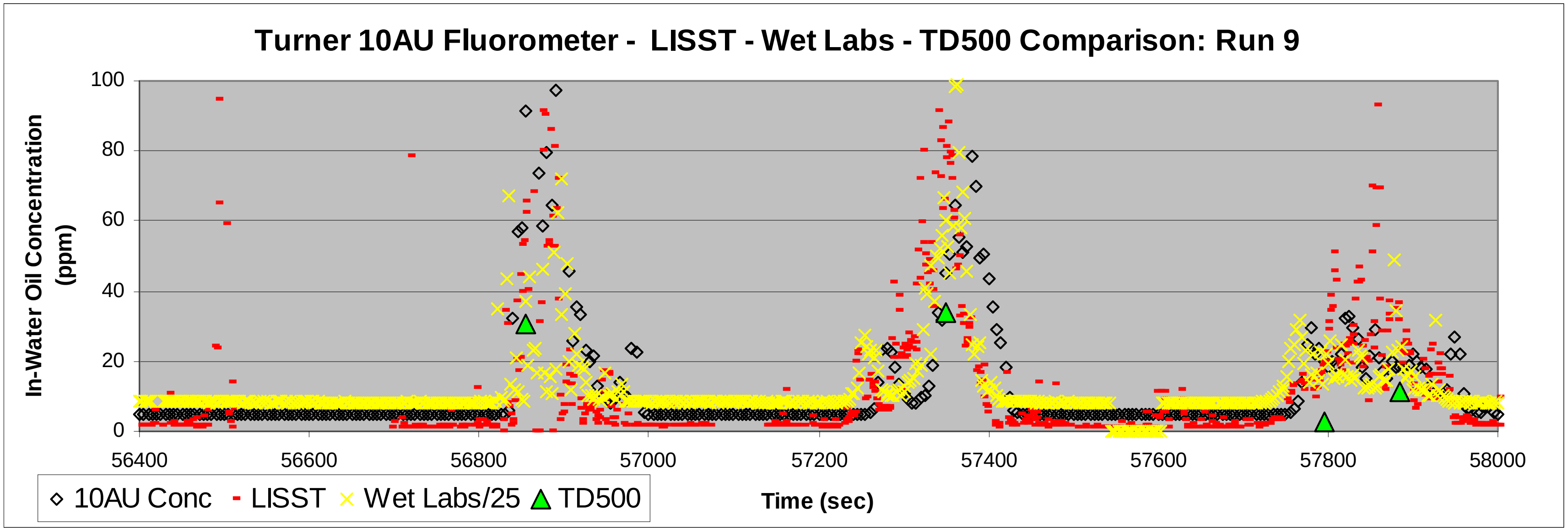

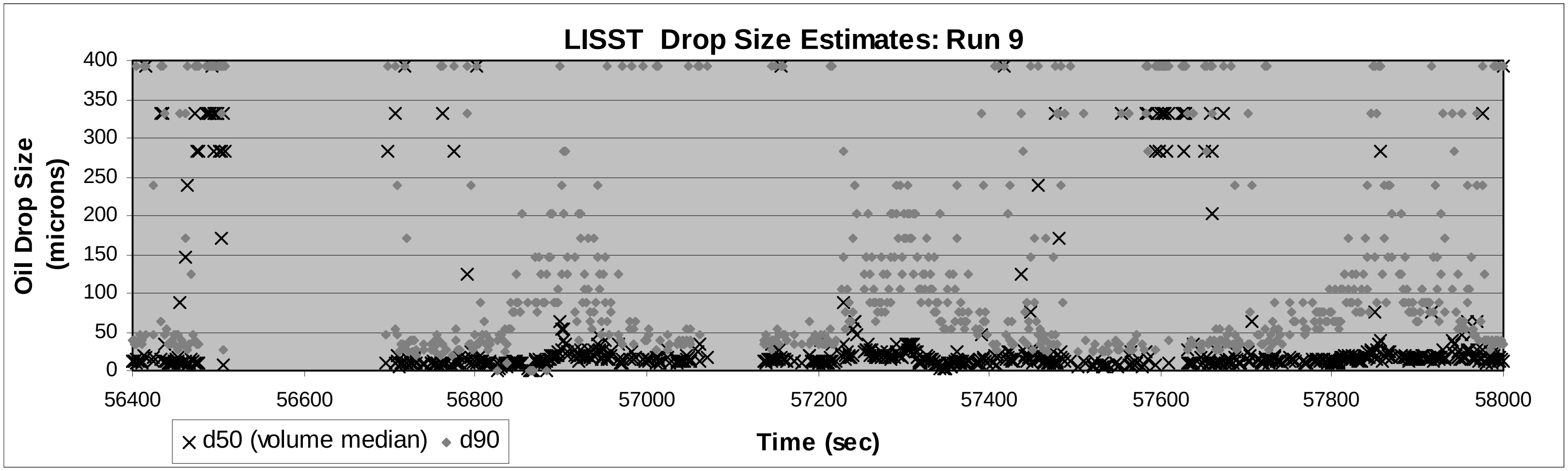

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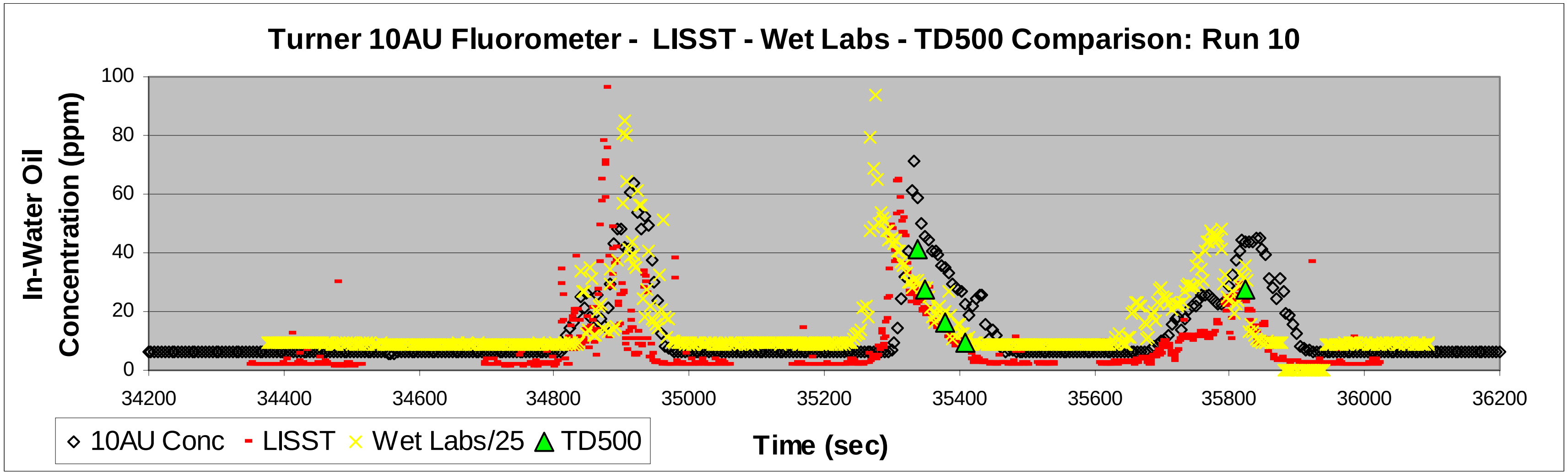

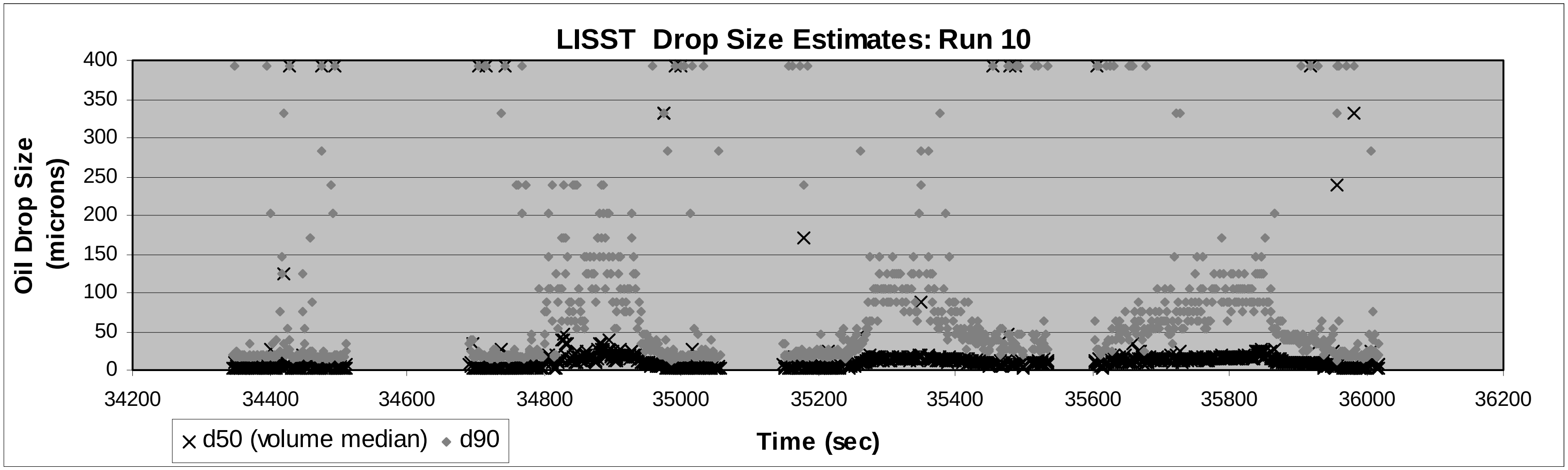

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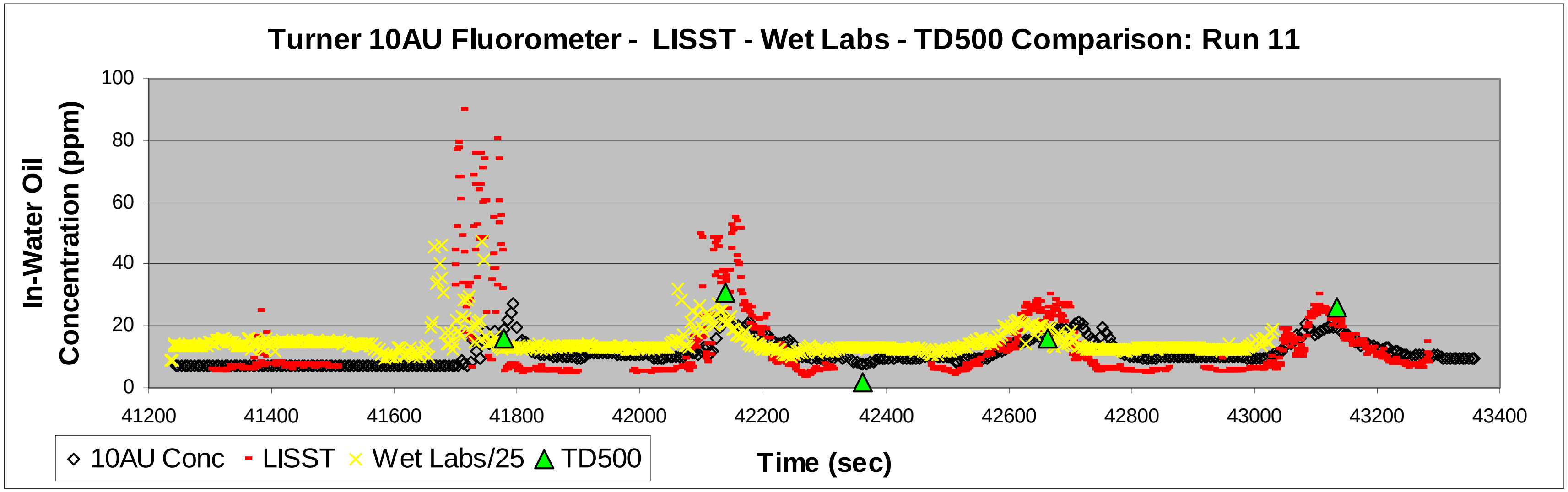

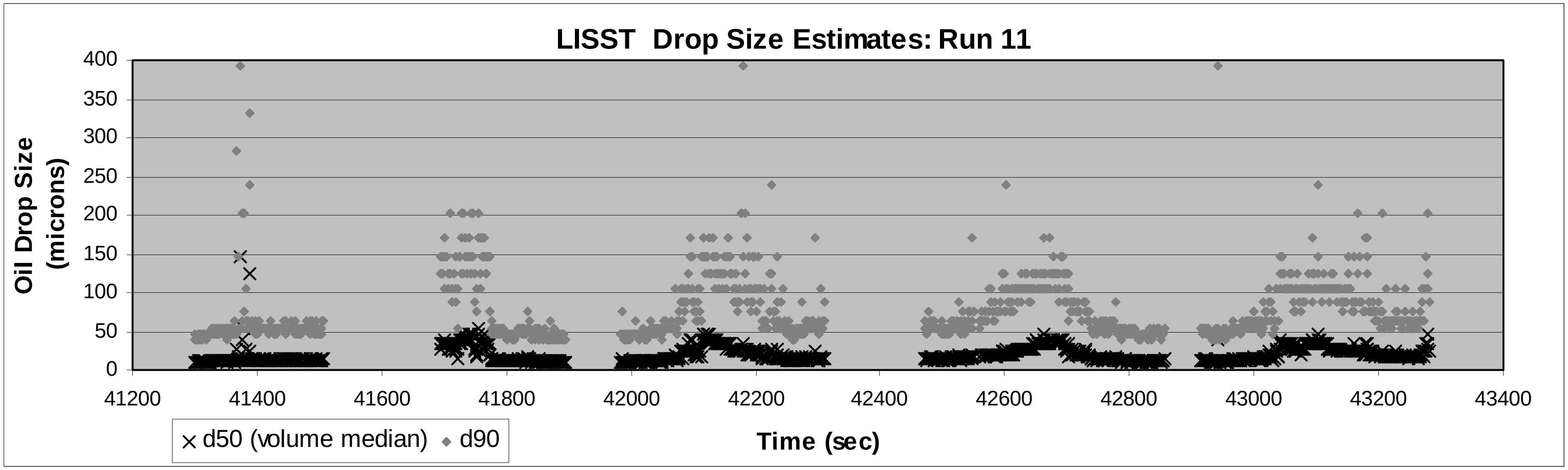

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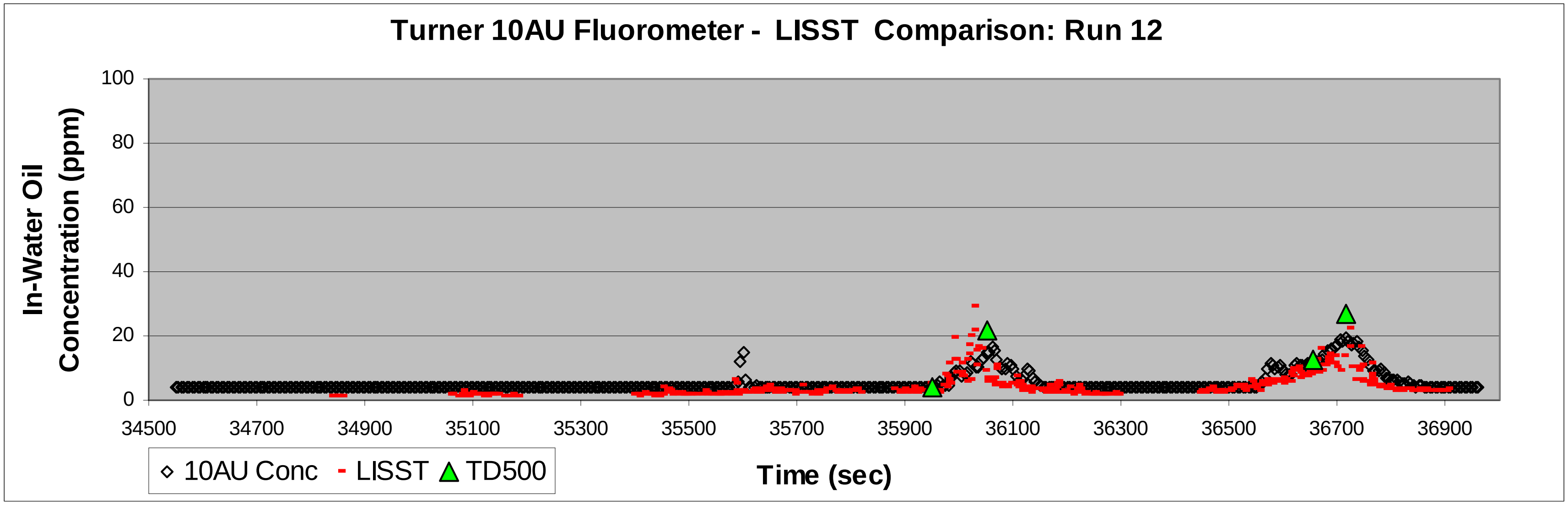

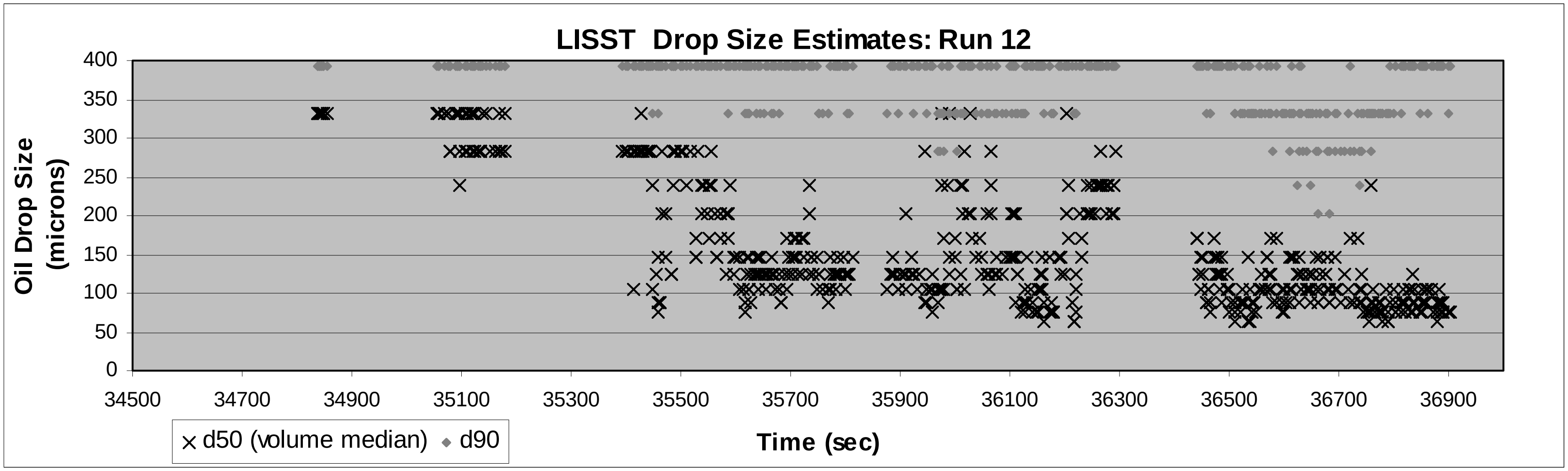

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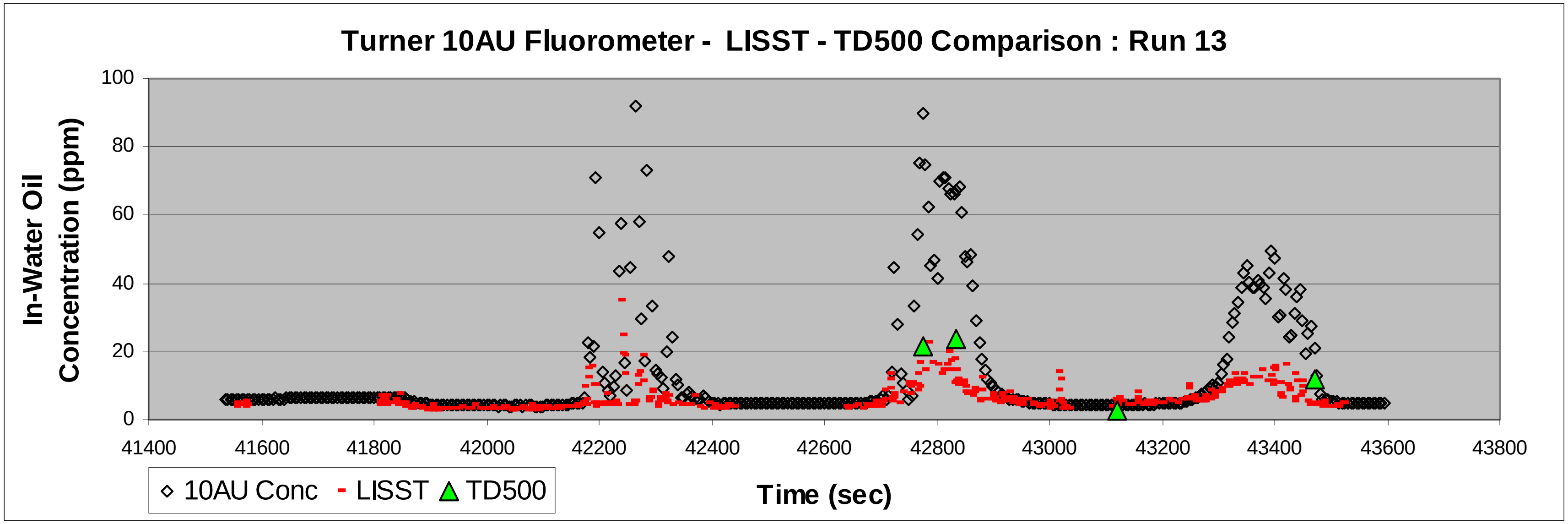

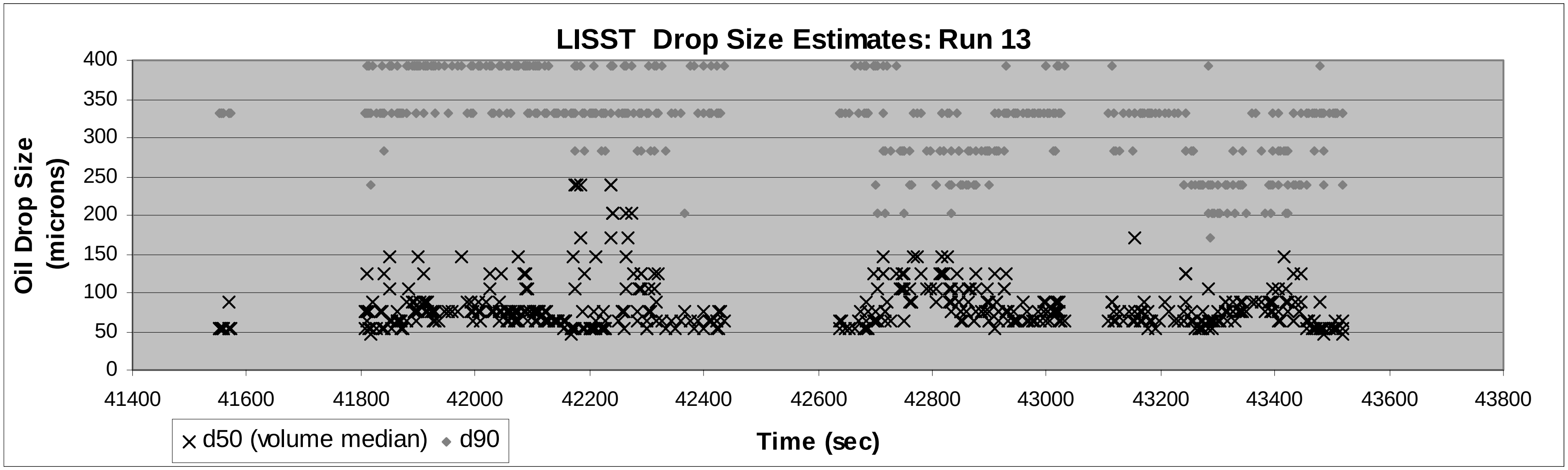

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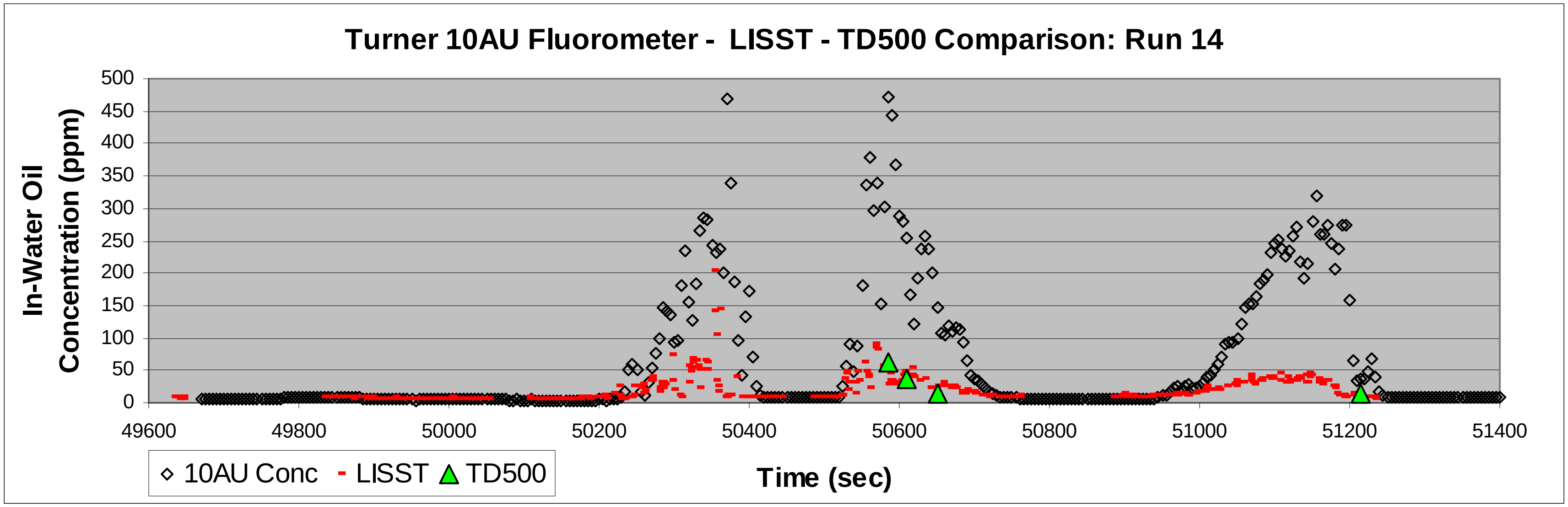

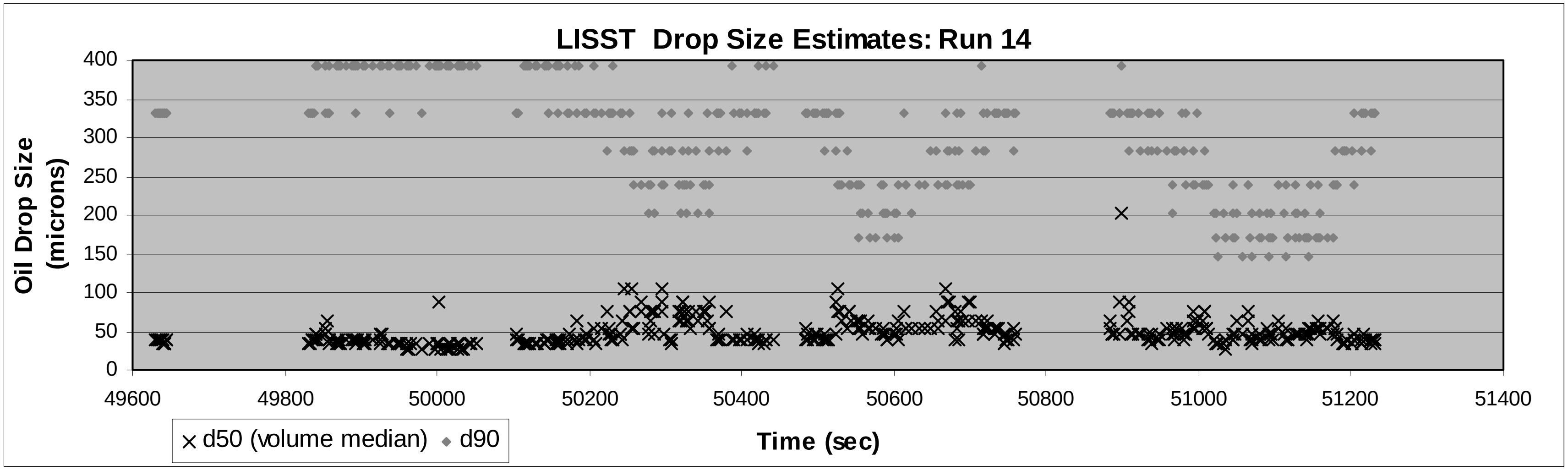

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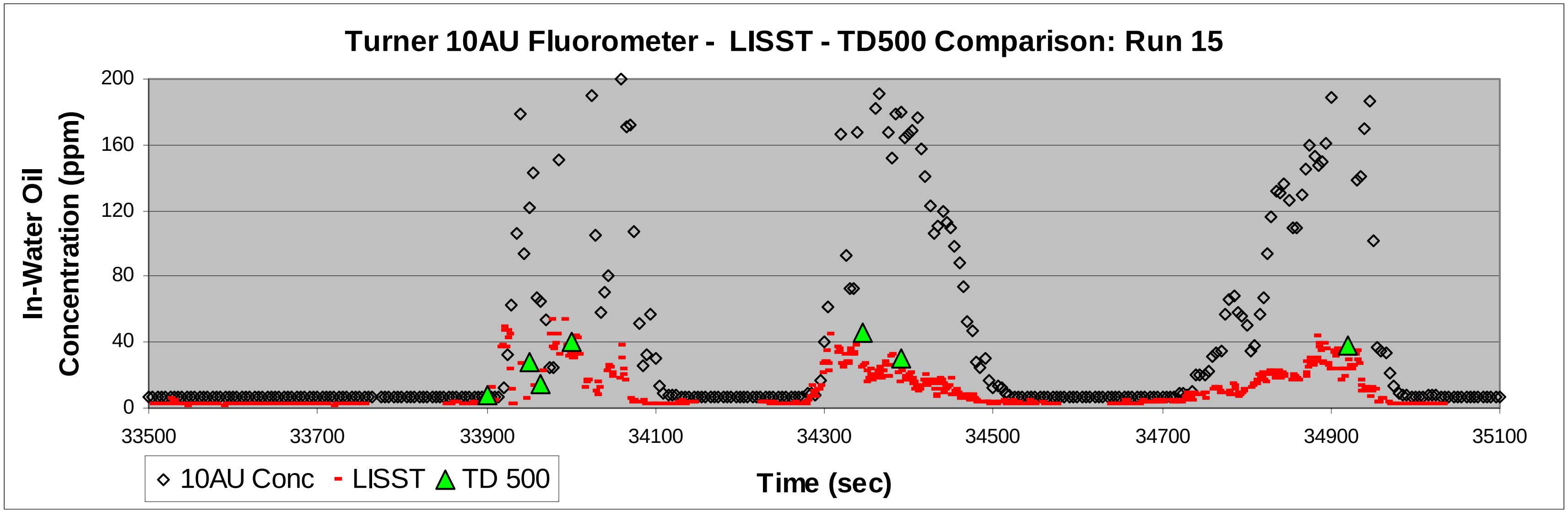

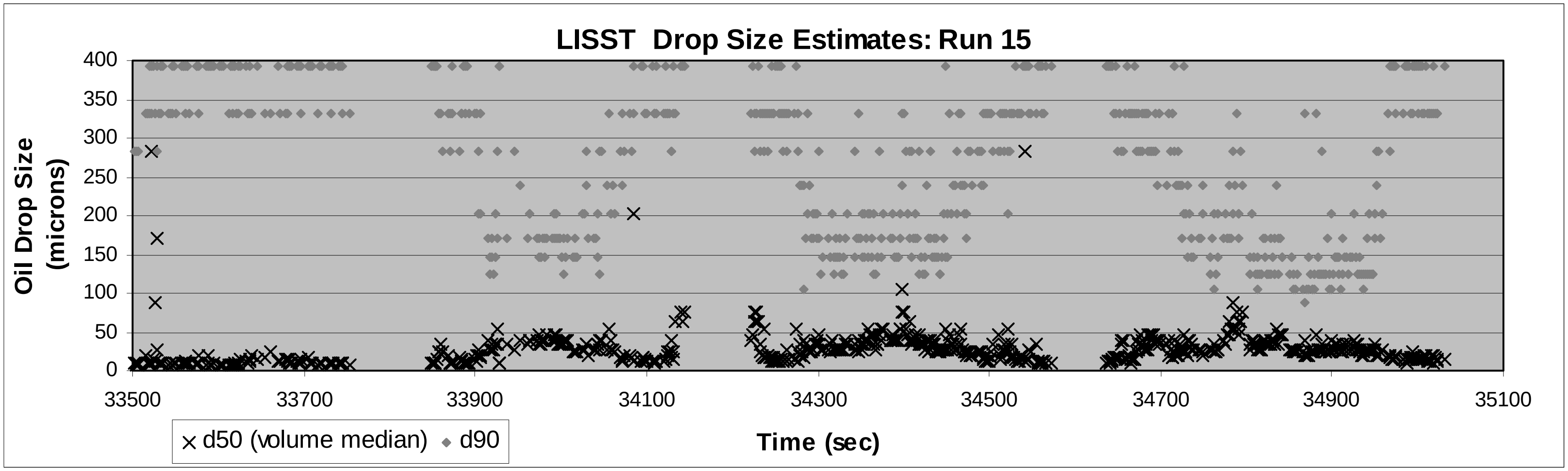

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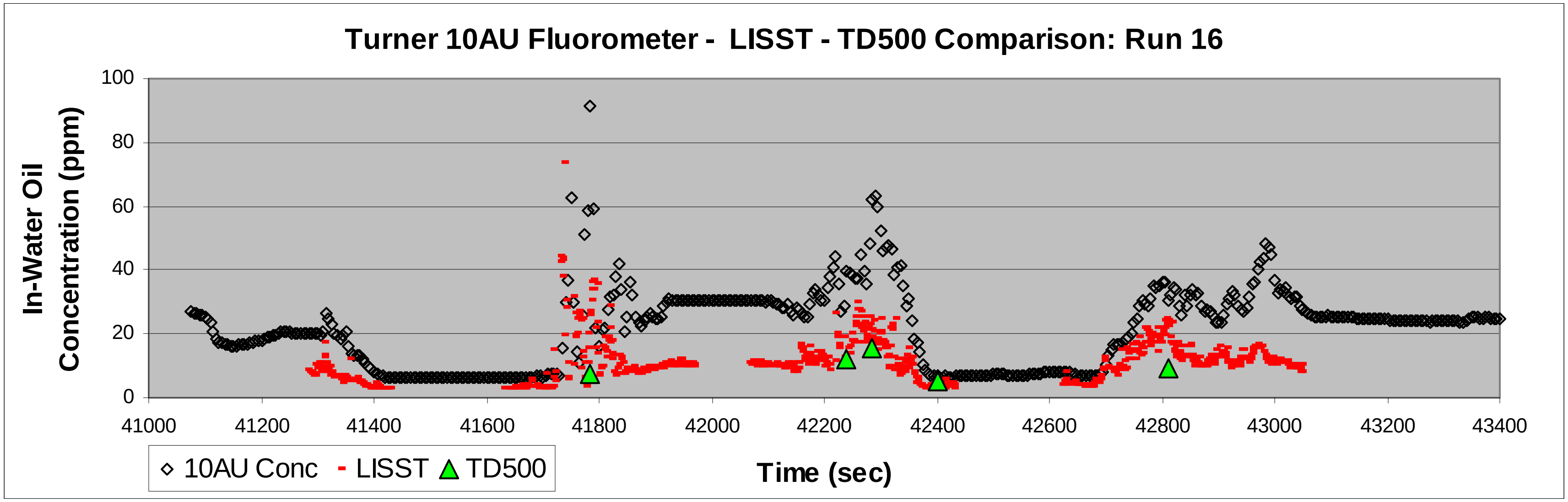

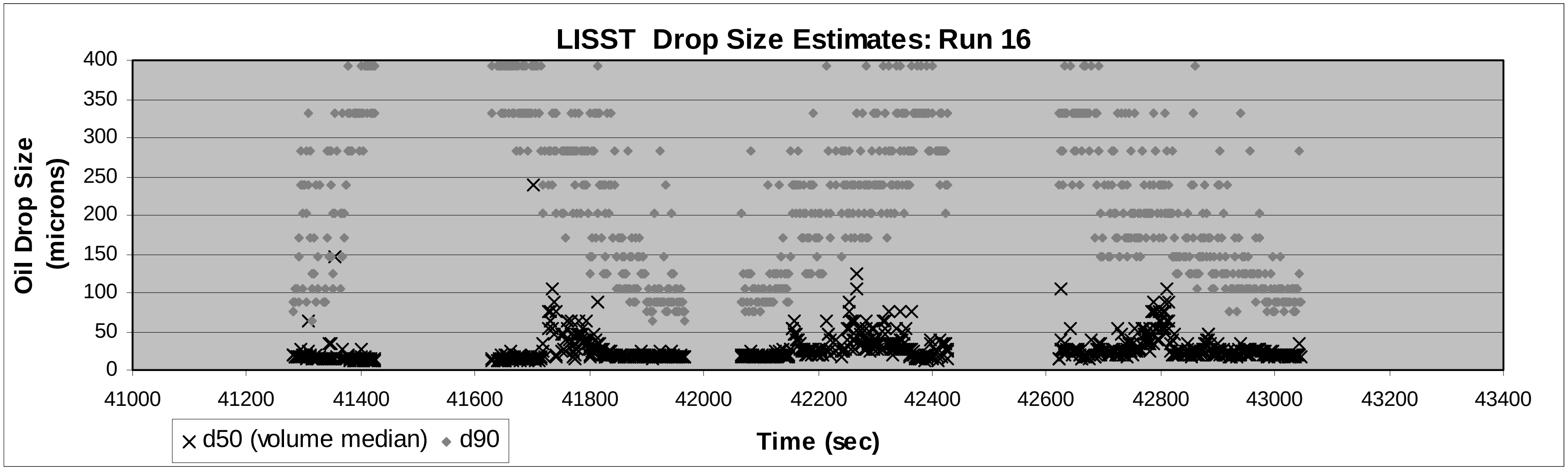

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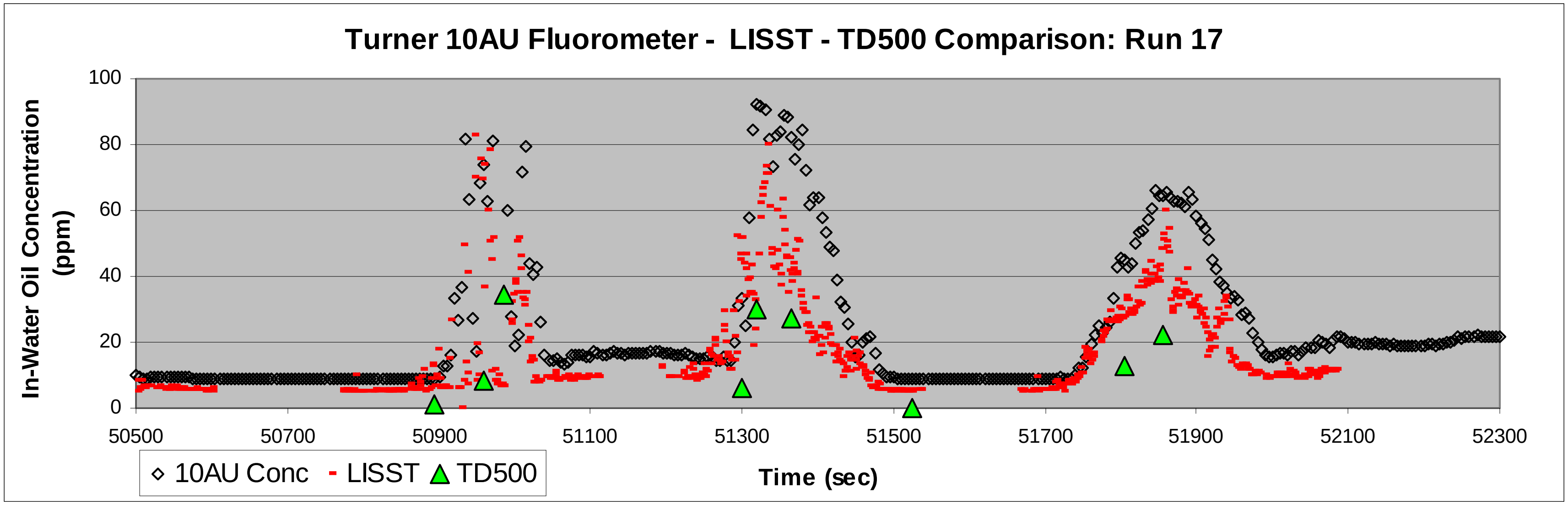

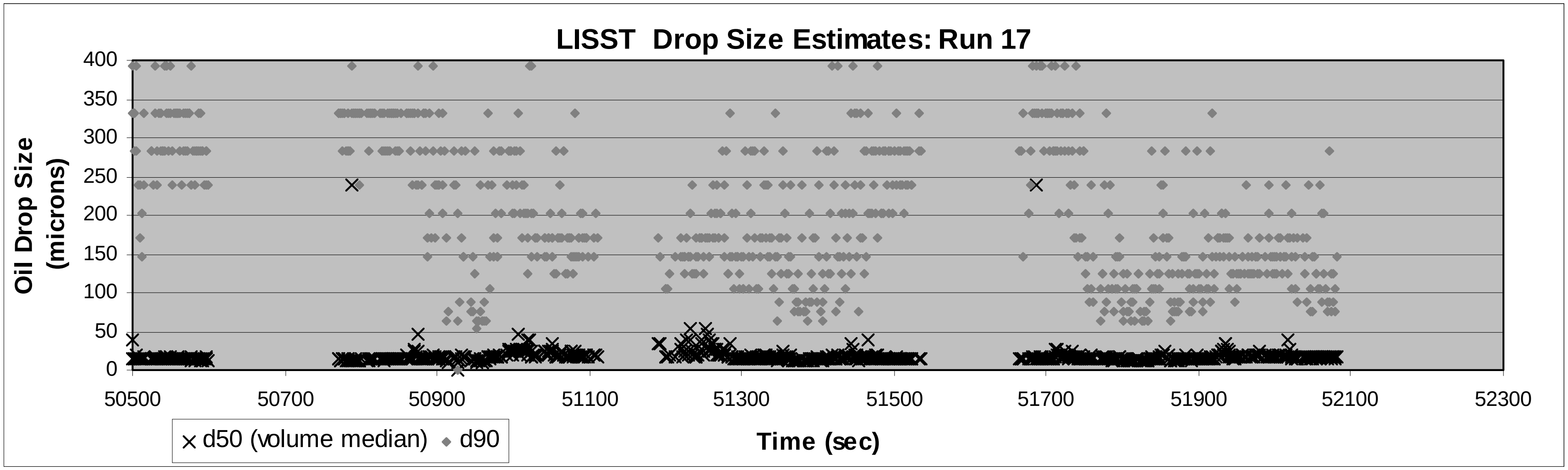

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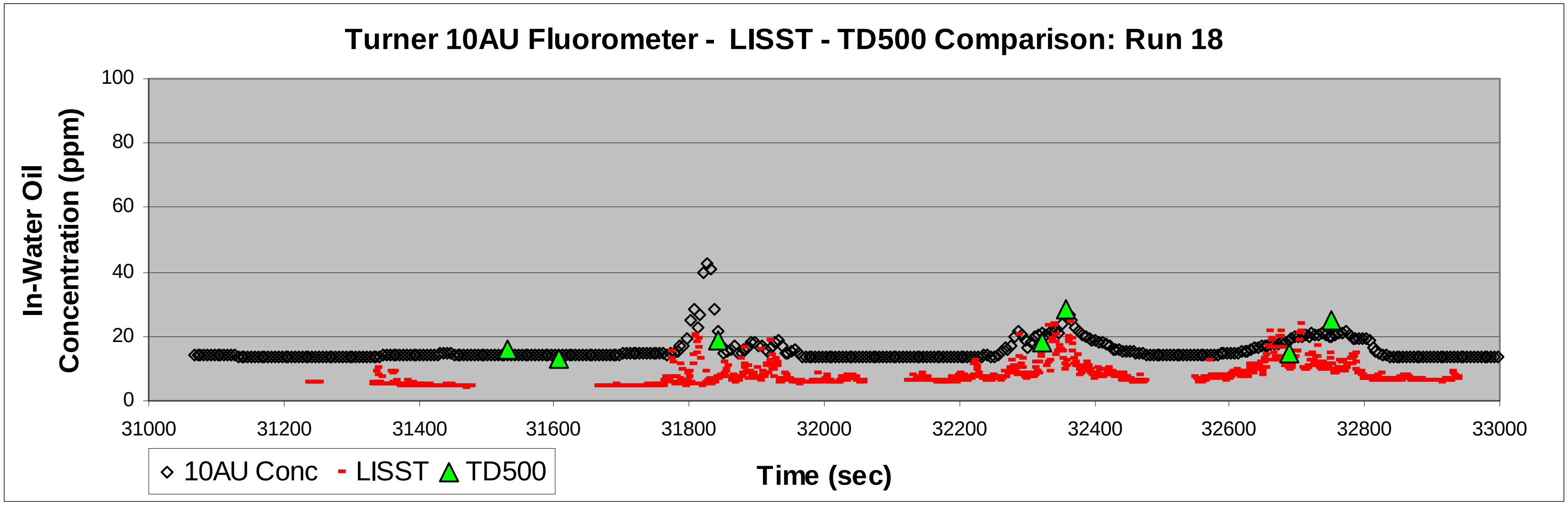

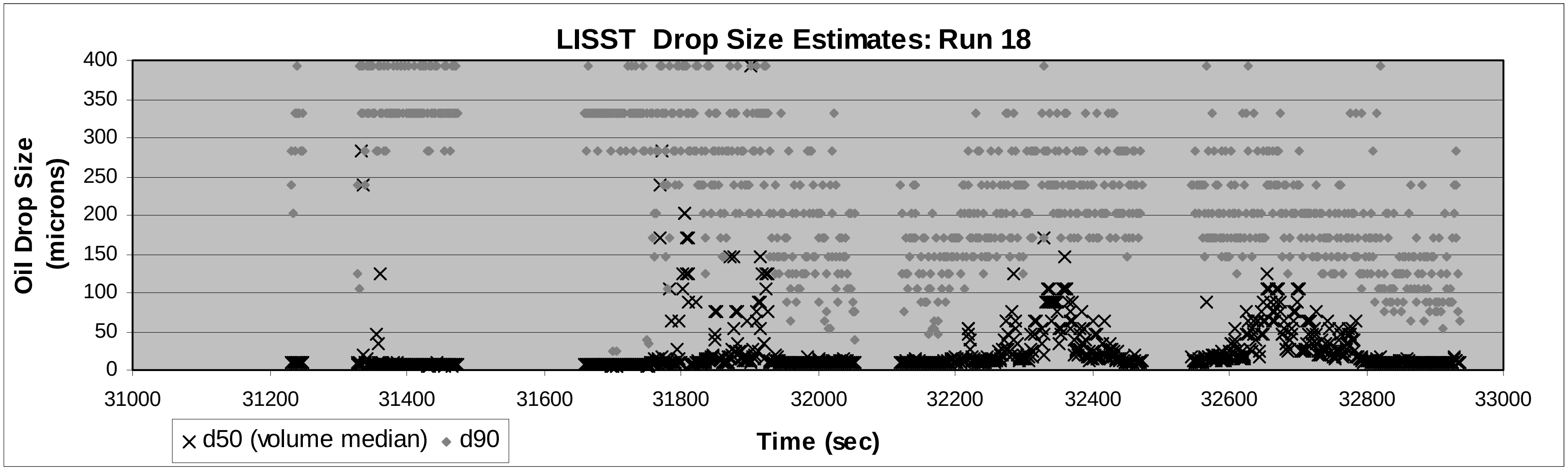

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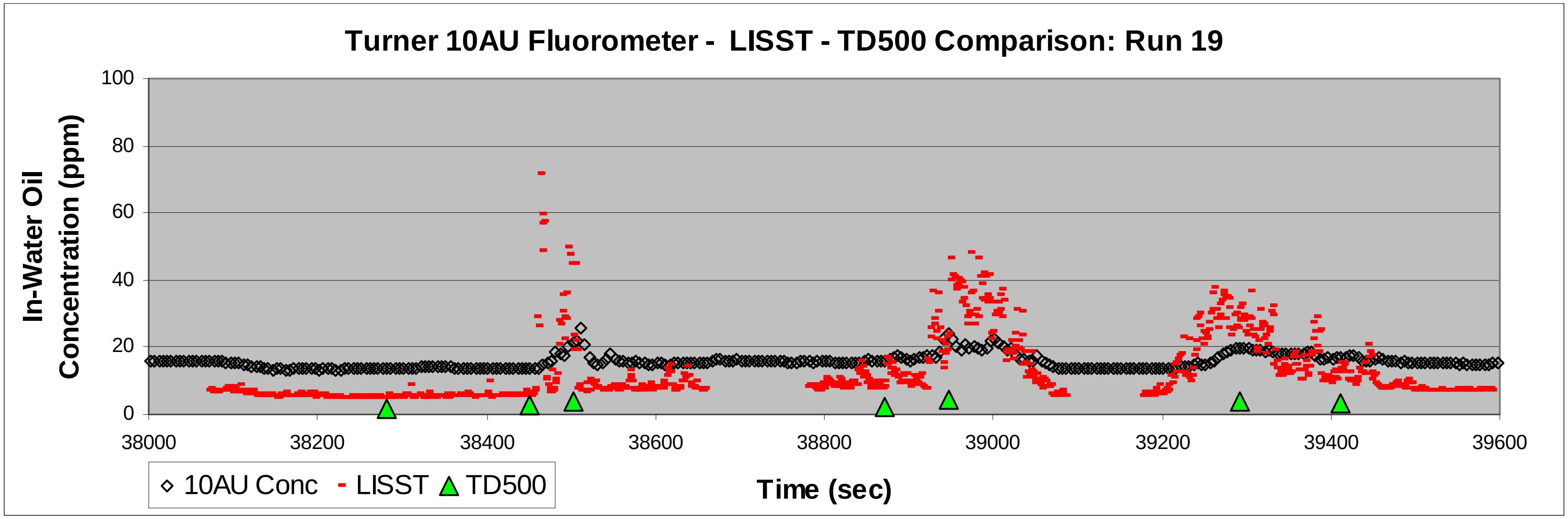

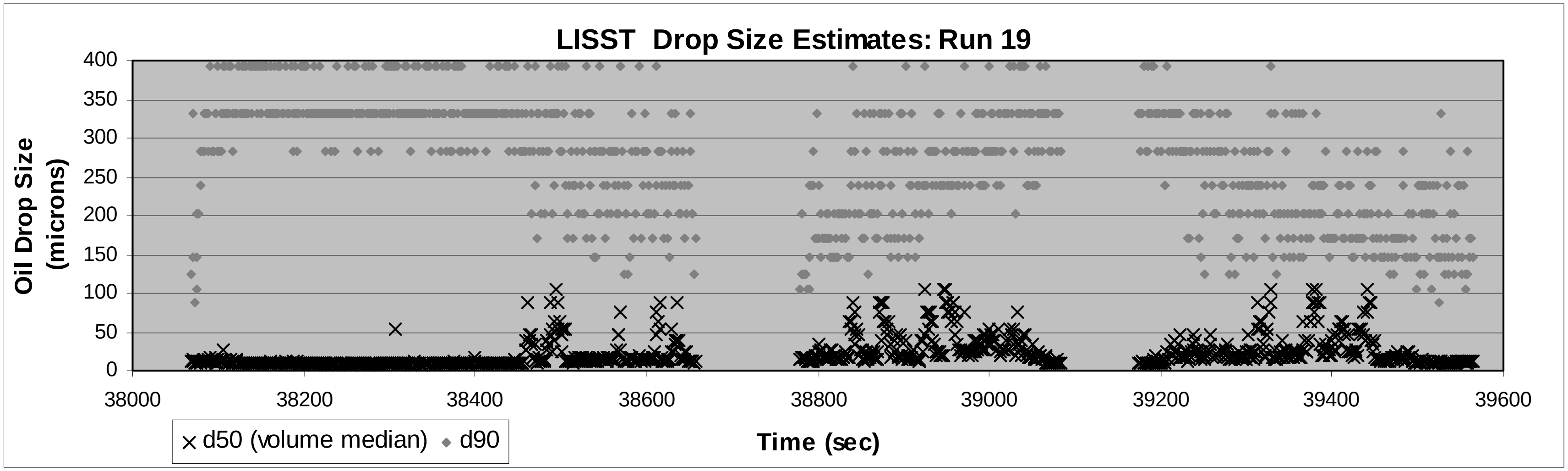

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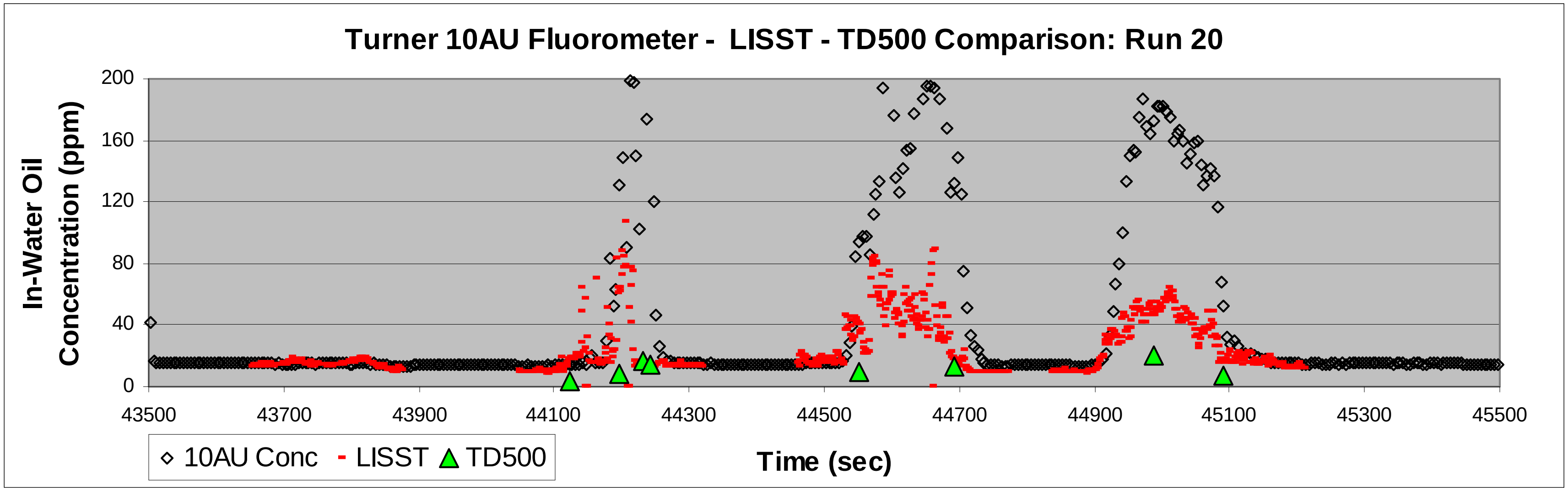

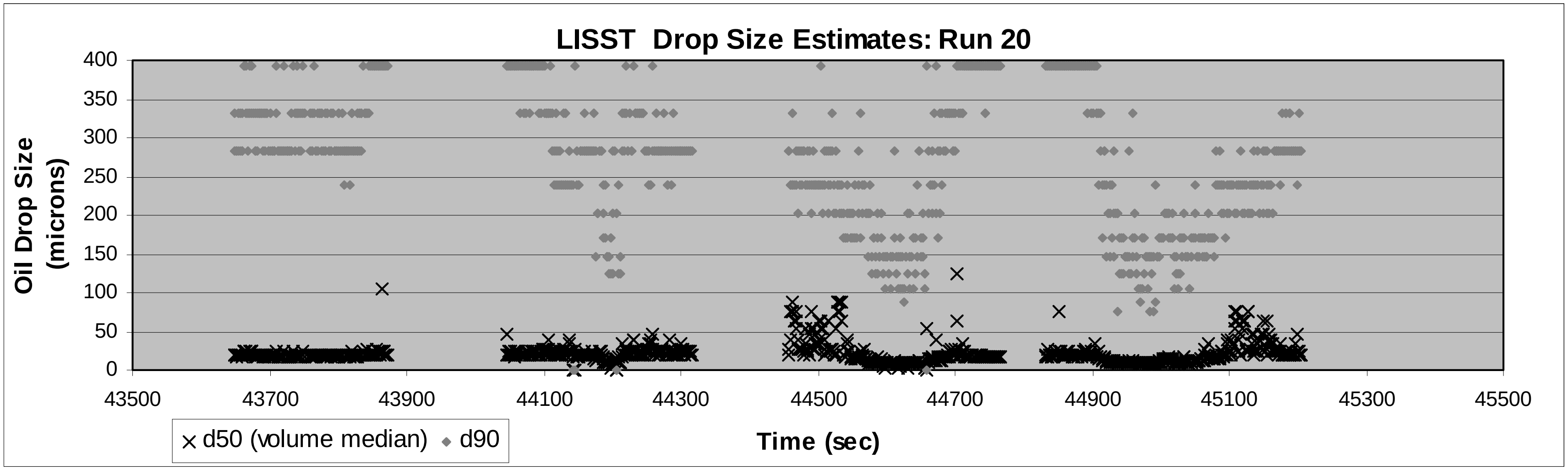

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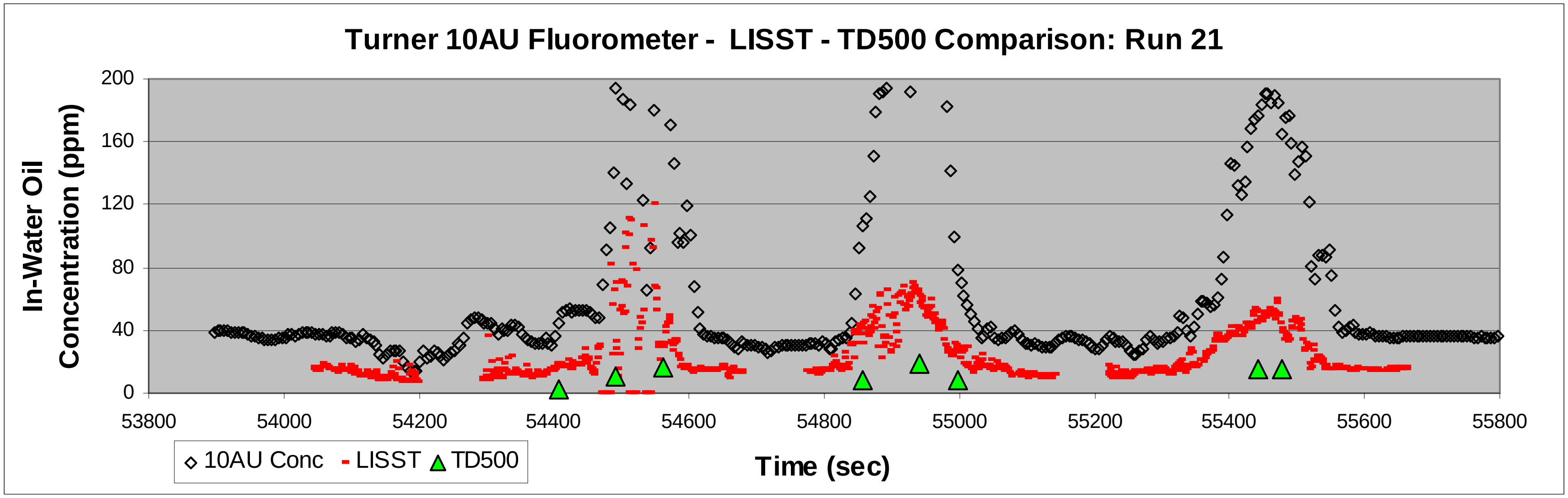

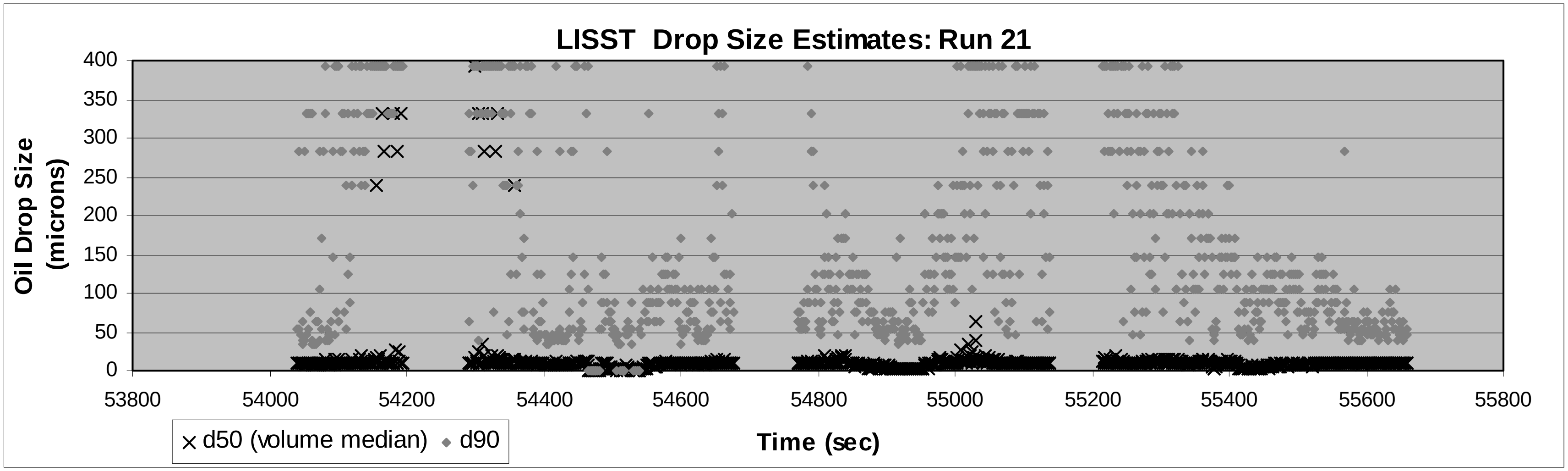

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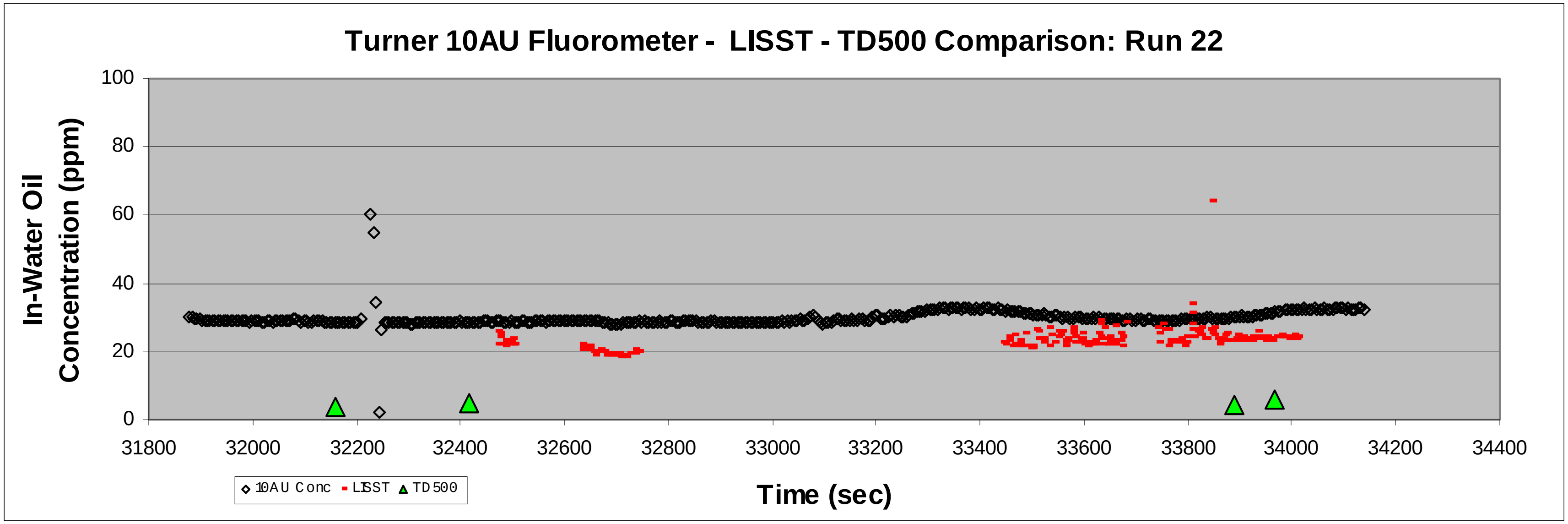

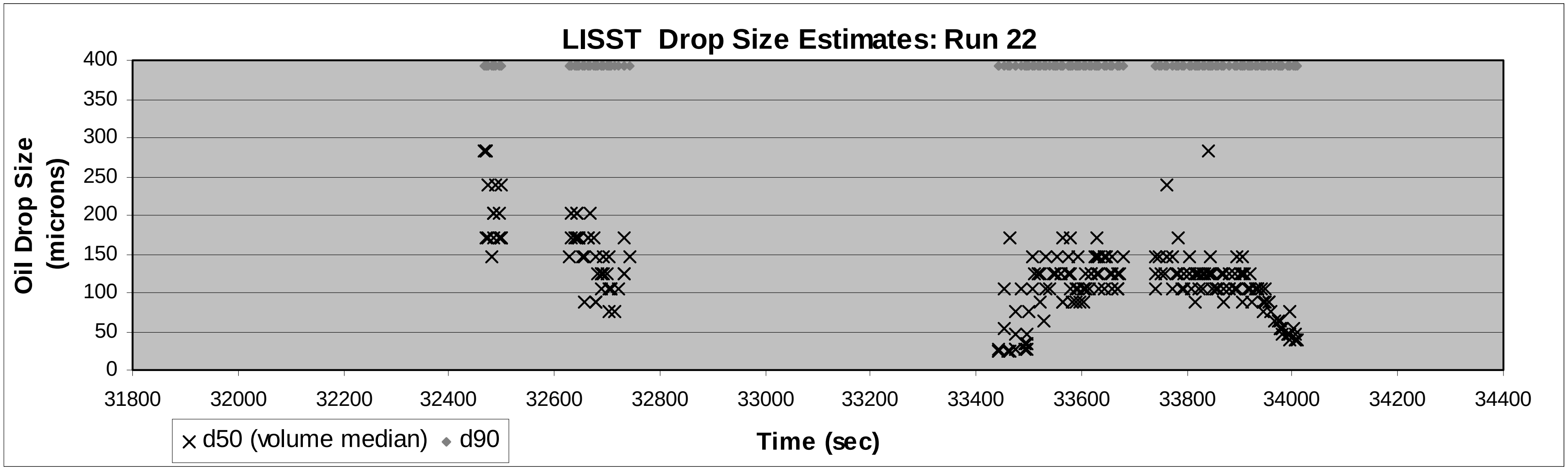

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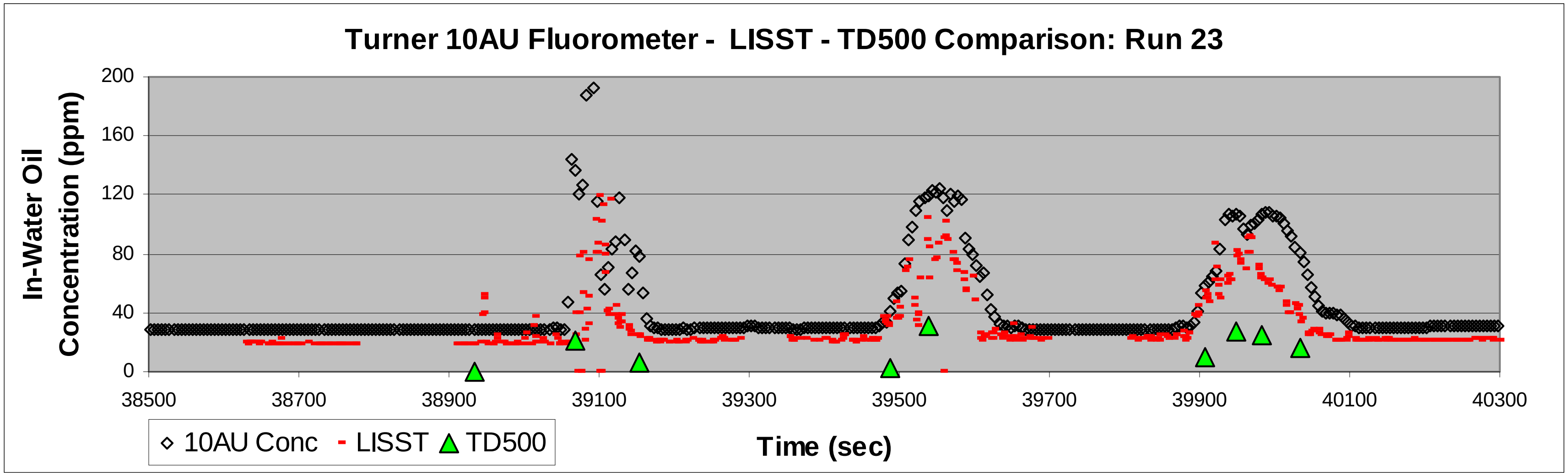

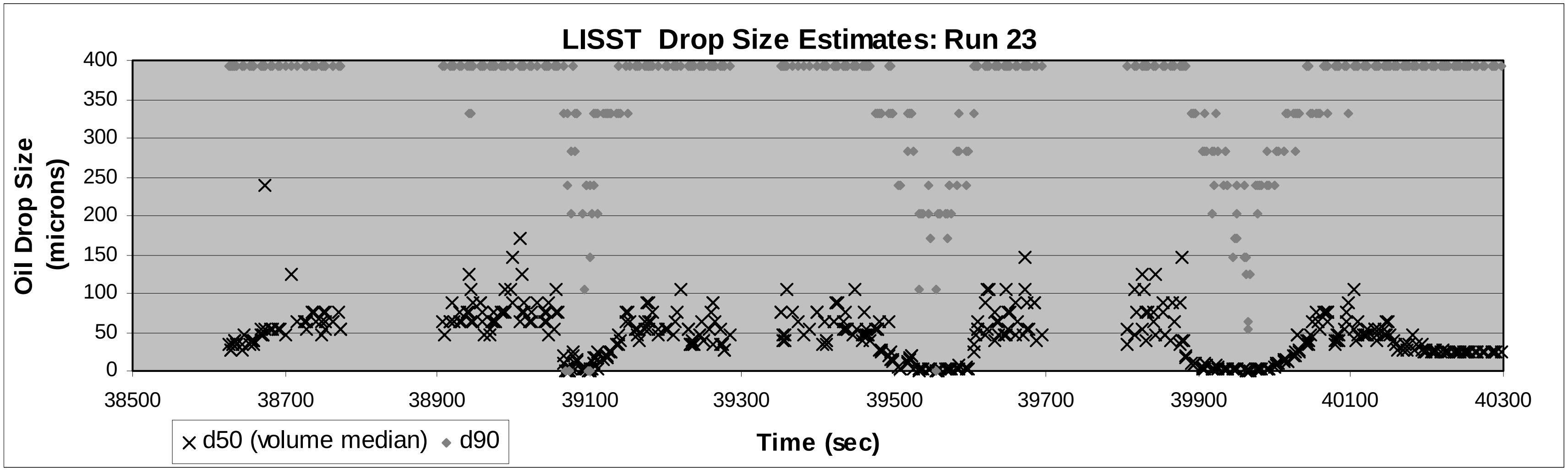

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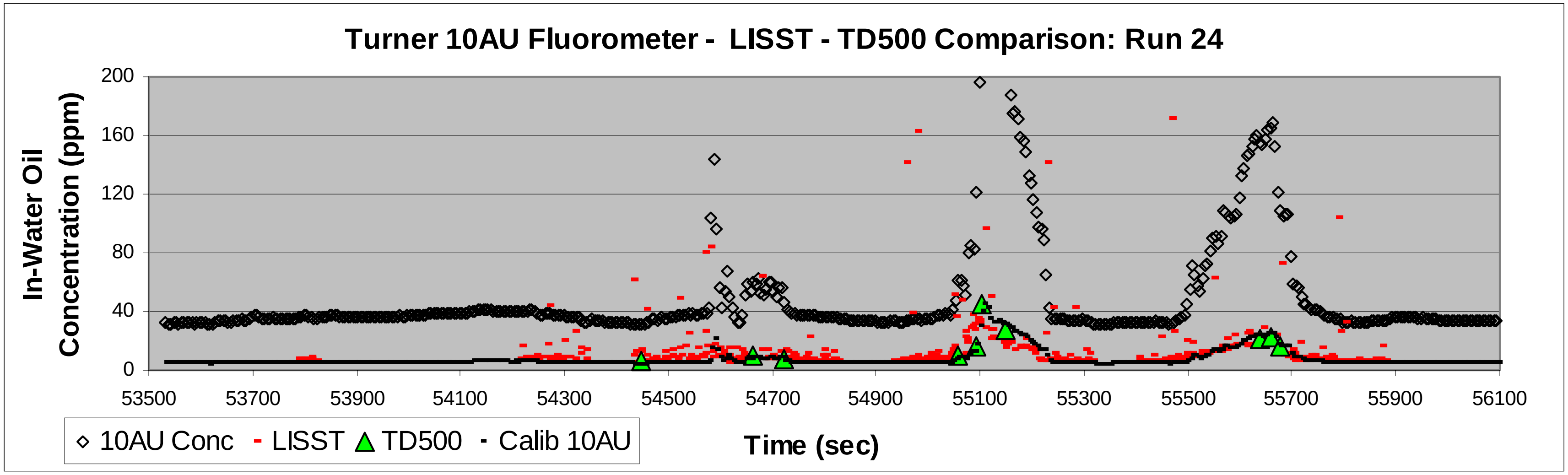

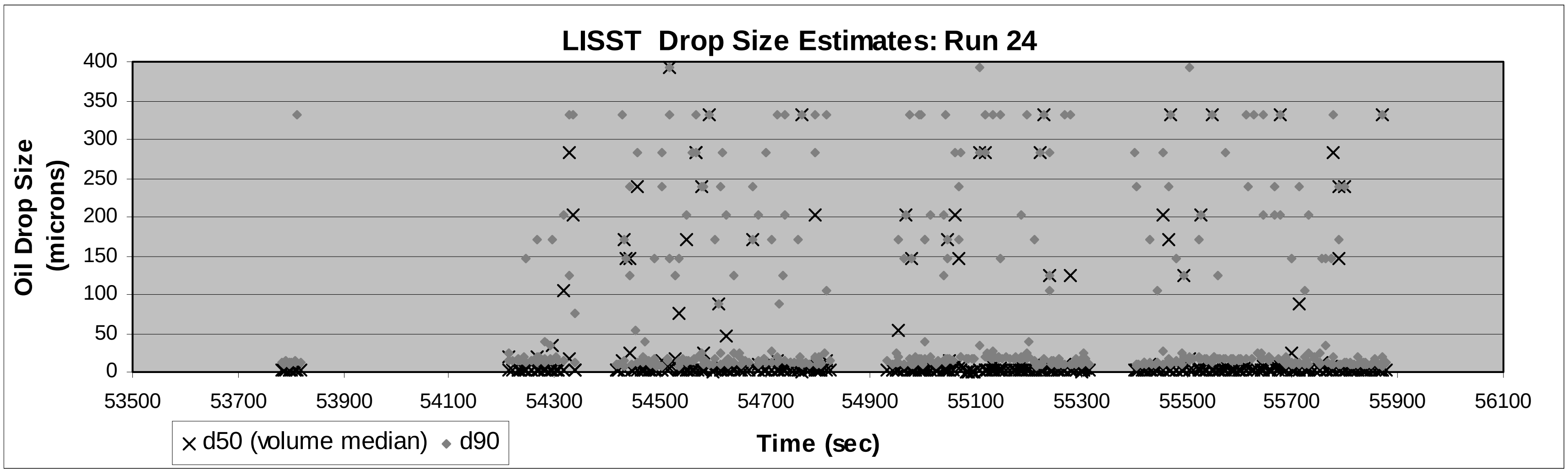

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