U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER (TARDEC)

Army Demonstration of Light Obscuration Particle Counters for Monitoring Aviation Fuel Contamination

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Report Documentation Page

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Project Background

- Evaluation of In-line and Laboratory Particle Counters for US Military applications:
  - AFCTK/PTK
  - PQAS-E
  - Online fuel contamination monitoring

- Tri-Service project funded by DLA-Energy
  - Army received $45,000

- Complimentary testing to programs completed by the Energy Institute, Navy, TFLRF, and Parker Hannifin

Project Background – Current Methods

Current methods:

- ASTM D2276 – Particulate Contamination in Aviation Fuel by Line Sampling
- ASTM D3240 – Undissolved Water in Aviation Turbine Fuels
- ASTM D4176 – Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)

Drawbacks:

- Operator Subjectivity
- Large sample volumes
- Potential Contamination

Project Background – Electronic Methods

DEF STAN 91-91 and MIL-DTL-83133 both include a report only requirement for particle counting

- IP 564 – Parker ACM20
- IP 565/ASTM D7619 – Stanhope-Seta AvCount
- IP 577 – Pamas S40

- Parker icountOS - Online instrument

Drawbacks to electronic methods

- Unable to distinguish between free water, sediment, and air bubbles

Objective

- Utilize existing particle counter technology to monitor aviation fuel quality for 5 days at 2 Army sites.

- Monitor fixed and mobile infrastructure points used to receive, store, and distribute aviation turbine fuel.

- Near real-time and laboratory non-subjective data analysis of the quality of aviation turbine fuel compared to military and industry accepted methods.

Electronic Sensor History

- Particle counting is not a new science
- Hydraulic industry has utilized this technology for decades and created a mature process
- Hydraulic industry has developed recognized calibration methodologies and standardized cleanliness code ratings
  - ISO 11171
  - ISO 4406
- Challenge – Being able to determine both particulate and water contamination

ISO/Range Code	Min. particles /mL	Max particles /mL
1	0	0.02
2	0.02	0.04
3	0.04	0.08
4	0.08	0.15
5	0.15	0.3
6	0.3	0.6
7	0.6	1.3
8	1.3	2.5
9	2.5	5
10	5	10
11	10	20
12	20	40
13	40	80
14	80	160
15	160	320
16	320	640
17	640	1,300
18	1,300	2,500
19	2,500	5,000
20	5,000	10,000
21	10,000	20,000
22	20,000	40,000
23	40,000	80,000
24	80,000	160,000
25	160,000	320,000
26	320,000	640,000
27	640,000	1,300,000
28	1,300,000	2,500,000
29	2,500,000	5,000,000
30	5,000,000	10,000,000

Proposed Particle Count Limits

	Receipt	Vehicle Fuel Tank	Fuel Injector
Aviation Fuel			
DEF (AUST) 5695B		18/16/13	
Parker	18/16/13	14/10/7	
Pamas/Parker/Particle Solutions	19/17/12		
U.S. Army	19/17/14/13*		
Diesel Fuel			
World Wide Fuel Charter 4th		18/16/13	
DEF (AUST) 5695B		18/16/13	
Bosch/Cummins		18/16/13	
Donaldson	22/21/18	14/13/11	12/9/6
Pall	17/15/12	15/14/11	12/9/6 11/8/7

* 4um (c)/ 6um (c)/ 14um (c)/ 30um (c)

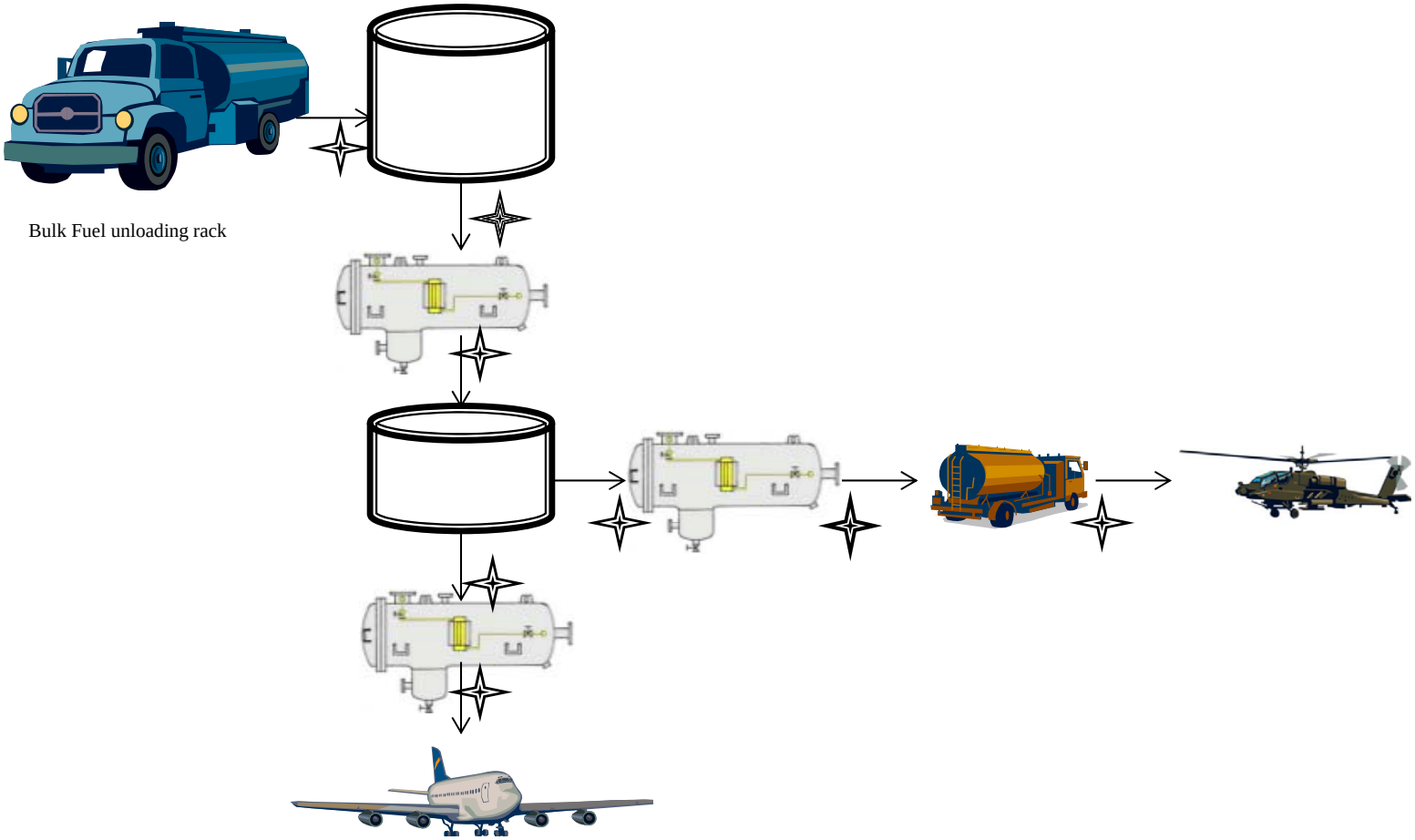
Evaluation Details

Two types of instruments

Online

Lab-based

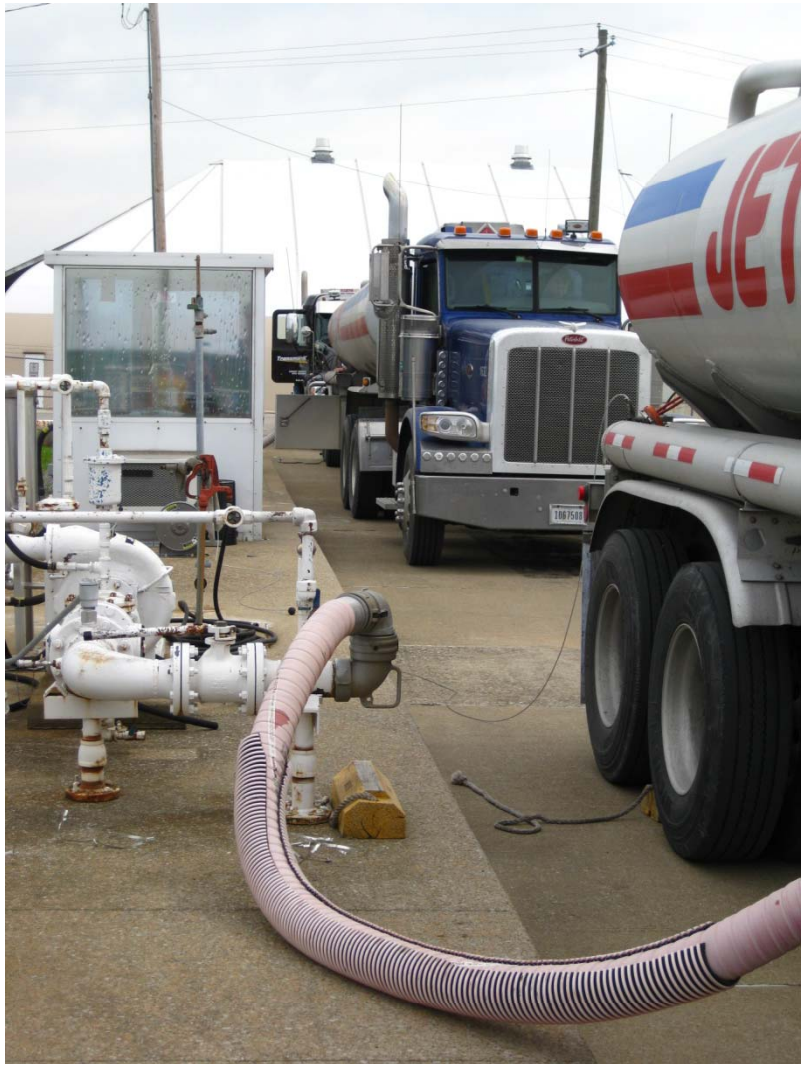
Site I– Fuel Distribution



Bulk Fuel unloading rack

Fuel sampling points

Site I– Bulk Delivery Offload



Site I – Bulk Sampling

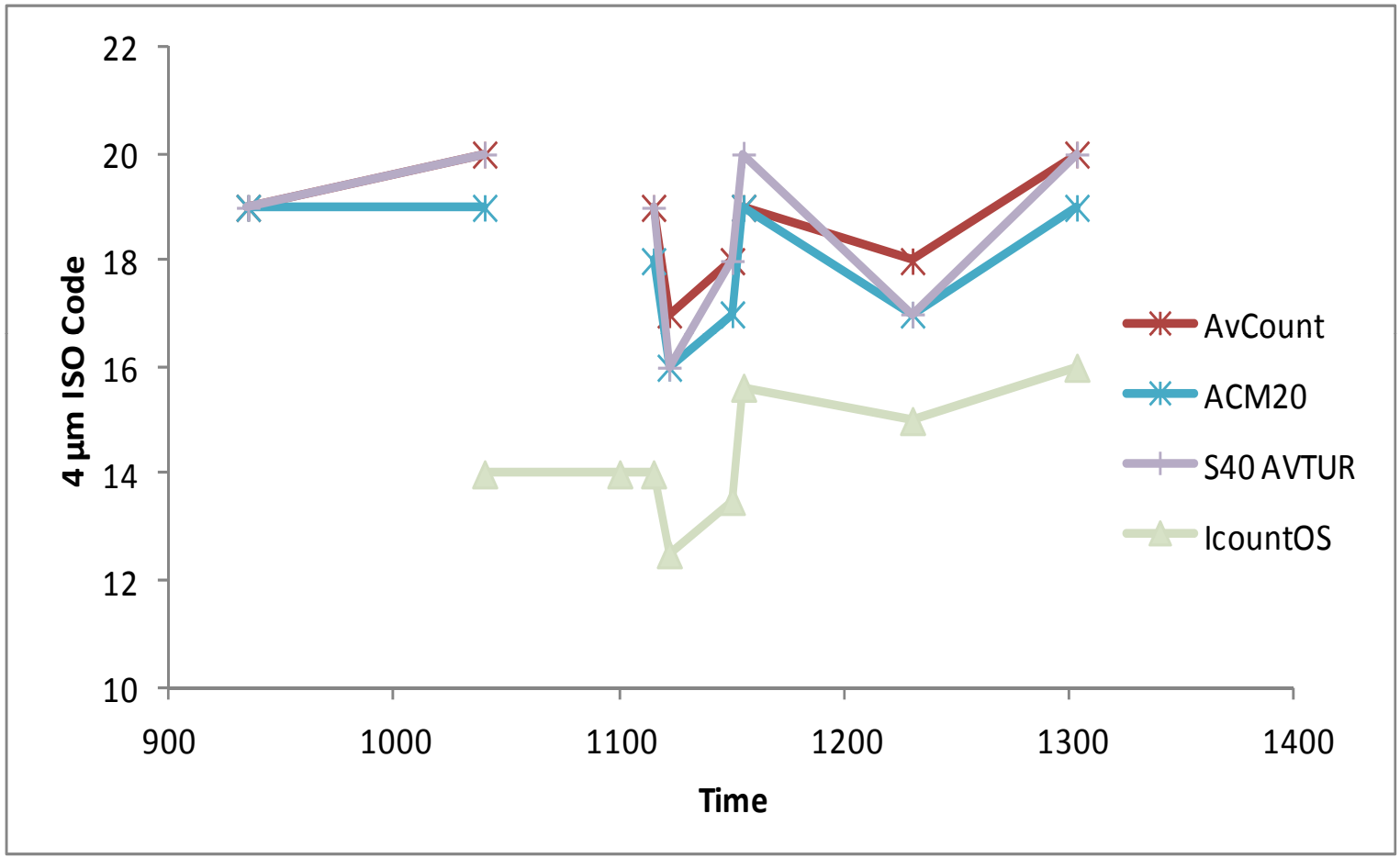
- Matched Weight Monitor Samples
- Aqua-Glo Sample (1L)
- 1-gallon sample for lab instruments

Site I – Bulk Sampling

Online instruments

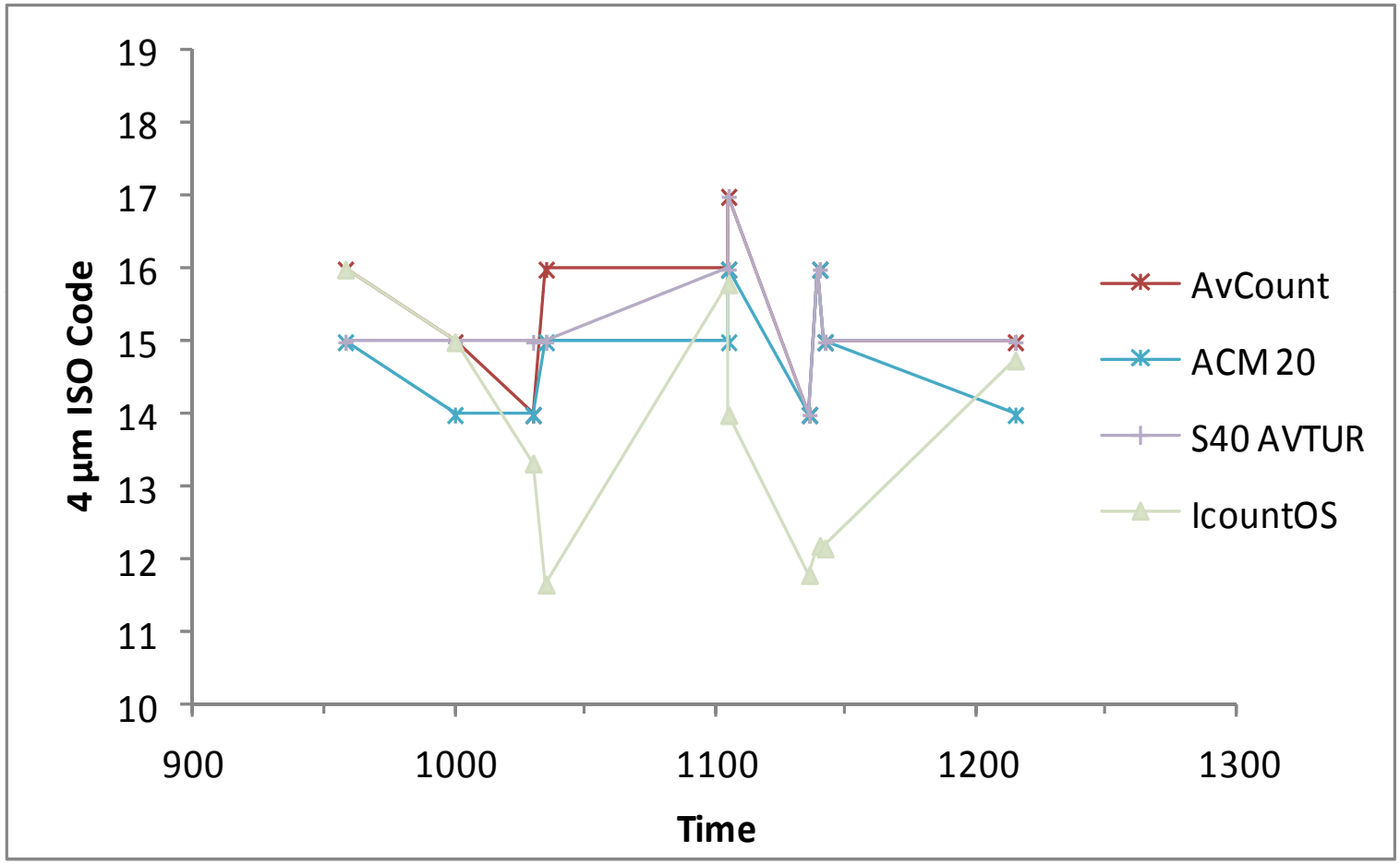
- Parker Hannifin icountOS
- Measuring particles in fuel flow from truck to bulk storage tank.
- Instrument averages 2 minutes of data.
- For our application, we manually started the pump.

Bulk Day 1


22
20
18
16
14
12
10
4 µm ISO Code
900
1000
1100
1200
1300
1400
Time
AvCount
ACM20
S40 AVTUR
IcountOS

Sample can contamination

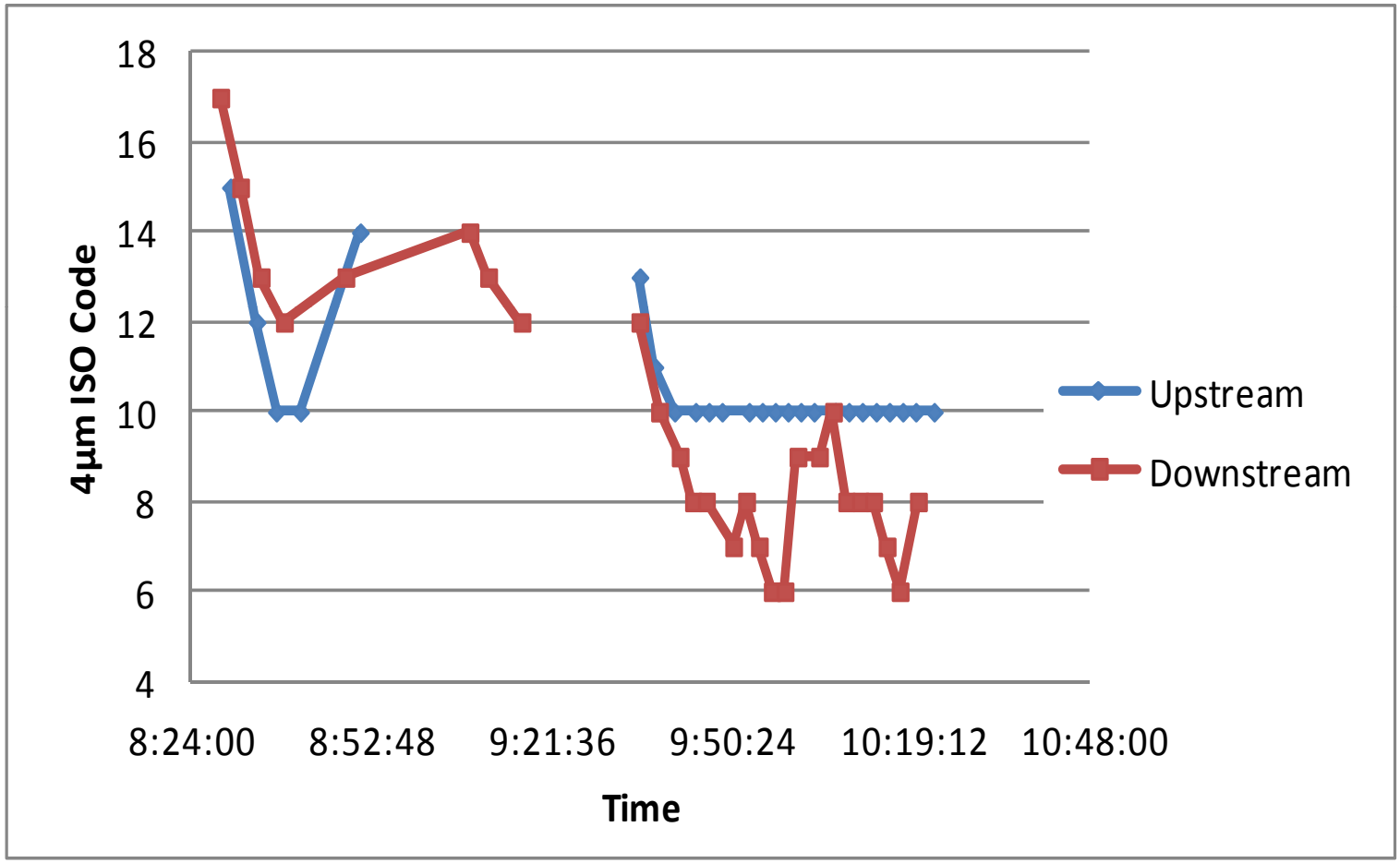
Bulk Day 2


19
18
17
16
15
14
13
12
11
10
4 µm ISO Code
900
1000
1100
1200
1300
Time
AvCount
ACM 20
S40 AVTUR
IcountOS

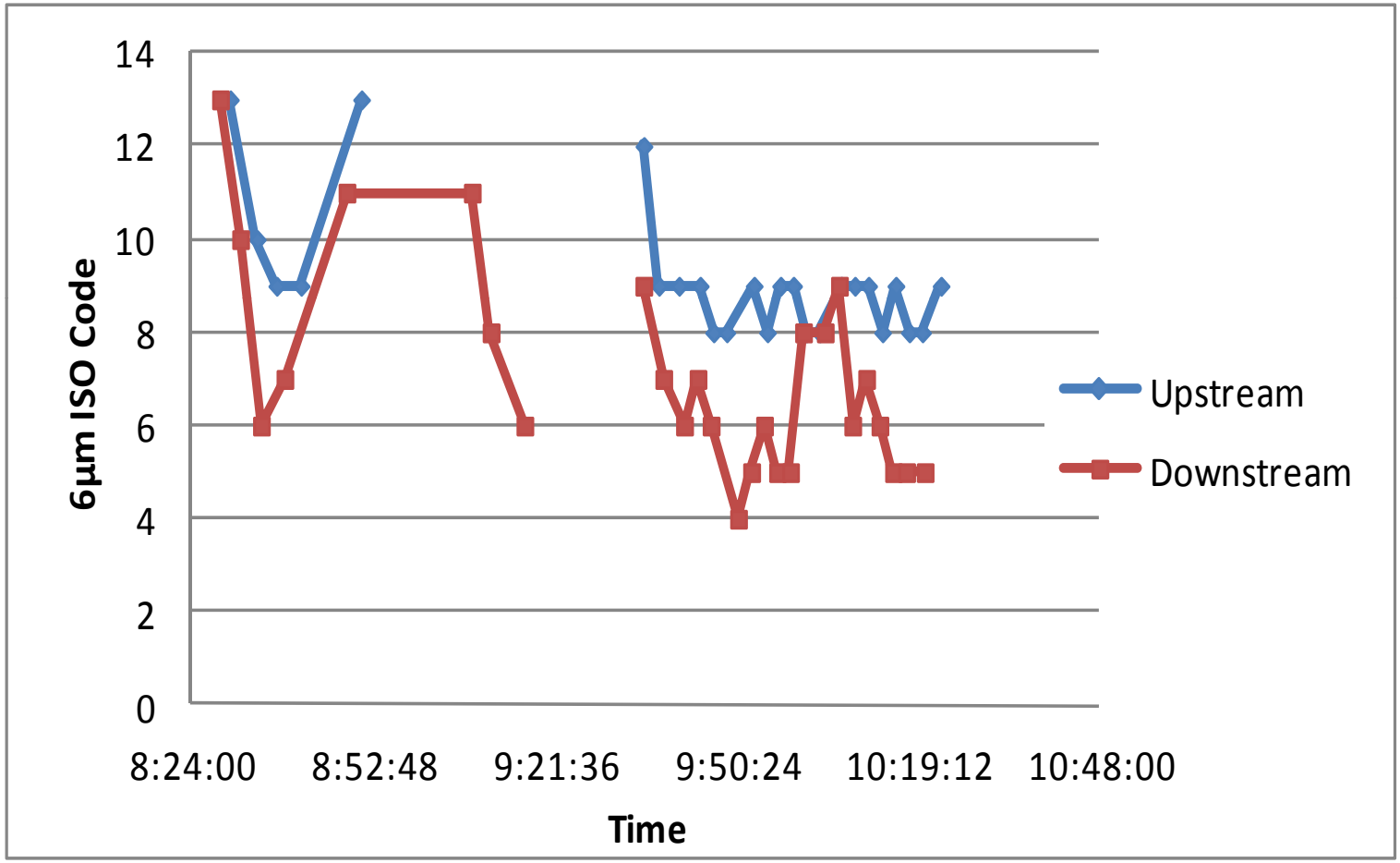
Site I – Transfer from Bulk Storage

• Samples taken upstream and downstream of the Filter Separator

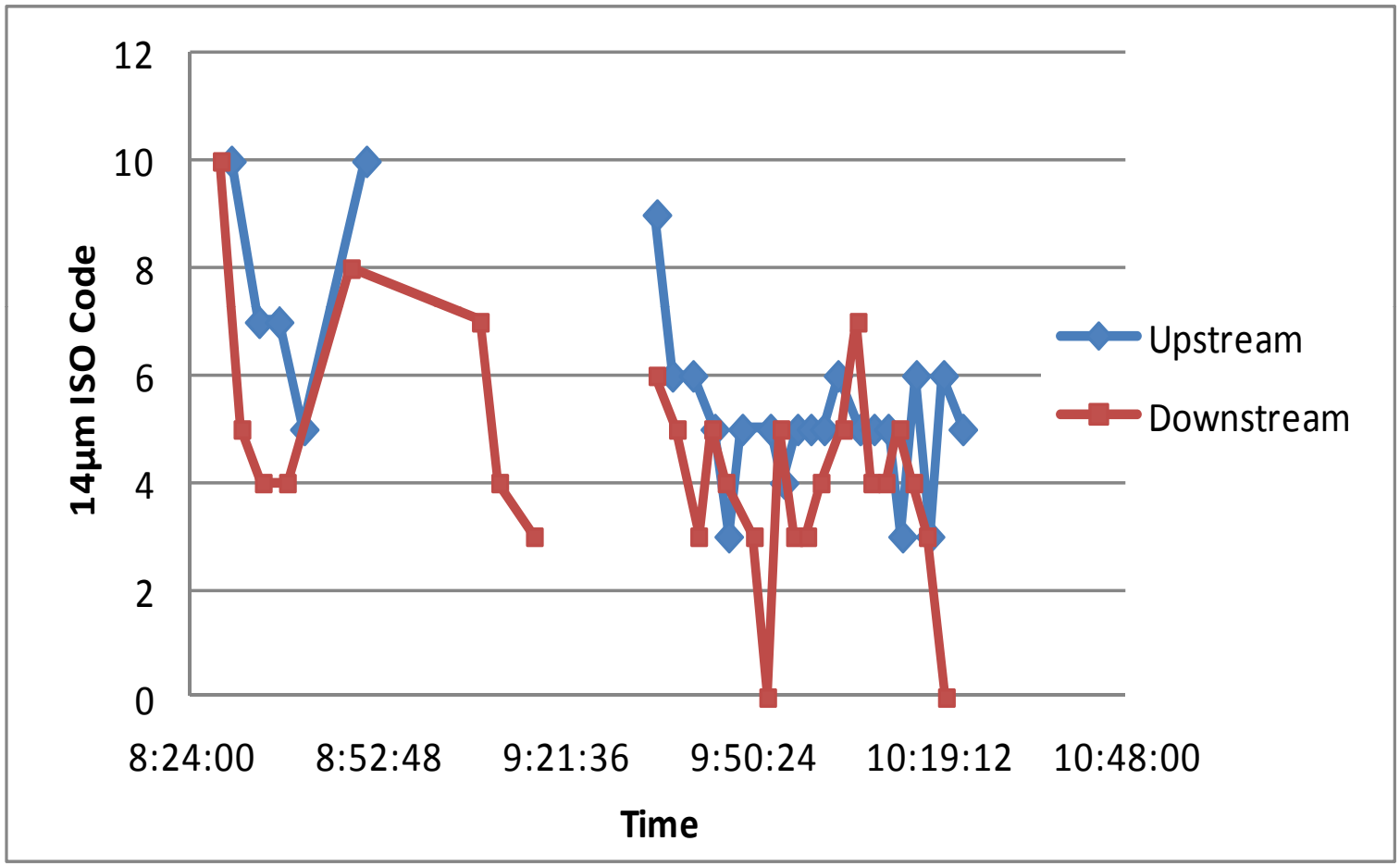
Site I – Transfer from Bulk Storage 4 micron



Site I – Transfer from Bulk Storage 6 micron



Site I– Transfer from Bulk Storage 14 micron



Site I – Transfer from Bulk Storage

Time (EST)	mg/L	Location	Lab ID	Avcount	ACM20 #1	ACM20 #2	S40 AVTUR #1	S40 AVTUR #2
830	1.11	Upstream	22	14/13/9/5	13/12/8/4	14/12/8/5	14/12/9/-	14/12/8/-
			22A	15/13/10/6	14/12/8/5	14/12/9/5	14/13/9/-	15/13/9/-
830	1.33	Downstream	23	14/12/9/4	13/12/8/4	14/12/9/5	14/12/9/-	14/12/9/-
			23A	15/13/10/7	14/12/9/5	14/12/9/5	15/13/10/-	15/13/9/-
918	0.60	Upstream	24	15/13/10/7	14/12/9/4	14/12/9/4	15/13/10/-	15/13/10/-
			24A	15/14/10/6	15/13/9/4	15/13/9/5	15/14/10/-	15/13/10/-
918	1.25	Downstream	25	15/13/9/5	14/12/8/4	14/12/8/4	14/13/9/-	14/12/9/-
			25A	16/14/11/7	15/13/8/7	15/13/10/6	15/14/10/-	15/14/10/-
1030	0.00	Upstream	26	14/12/9/5	14/12/8/0	14/12/8/4	14/12/9/-	15/12/9/-
			26A	15/13/10/6	14/13/9/4	14/13/9/5	15/13/10/-	15/13/10/-
1030	2.00*	Downstream	27	16/13/9/5	15/12/8/5	15/12/8/4	15/12/8/-	15/12/9/-
			27A	16/14/10/6	15/13/9/5	15/13/9/5	16/13/10/-	16/13/10/-

Site I – Fuel Dispensing

Dispensing Station for Refueling Trucks

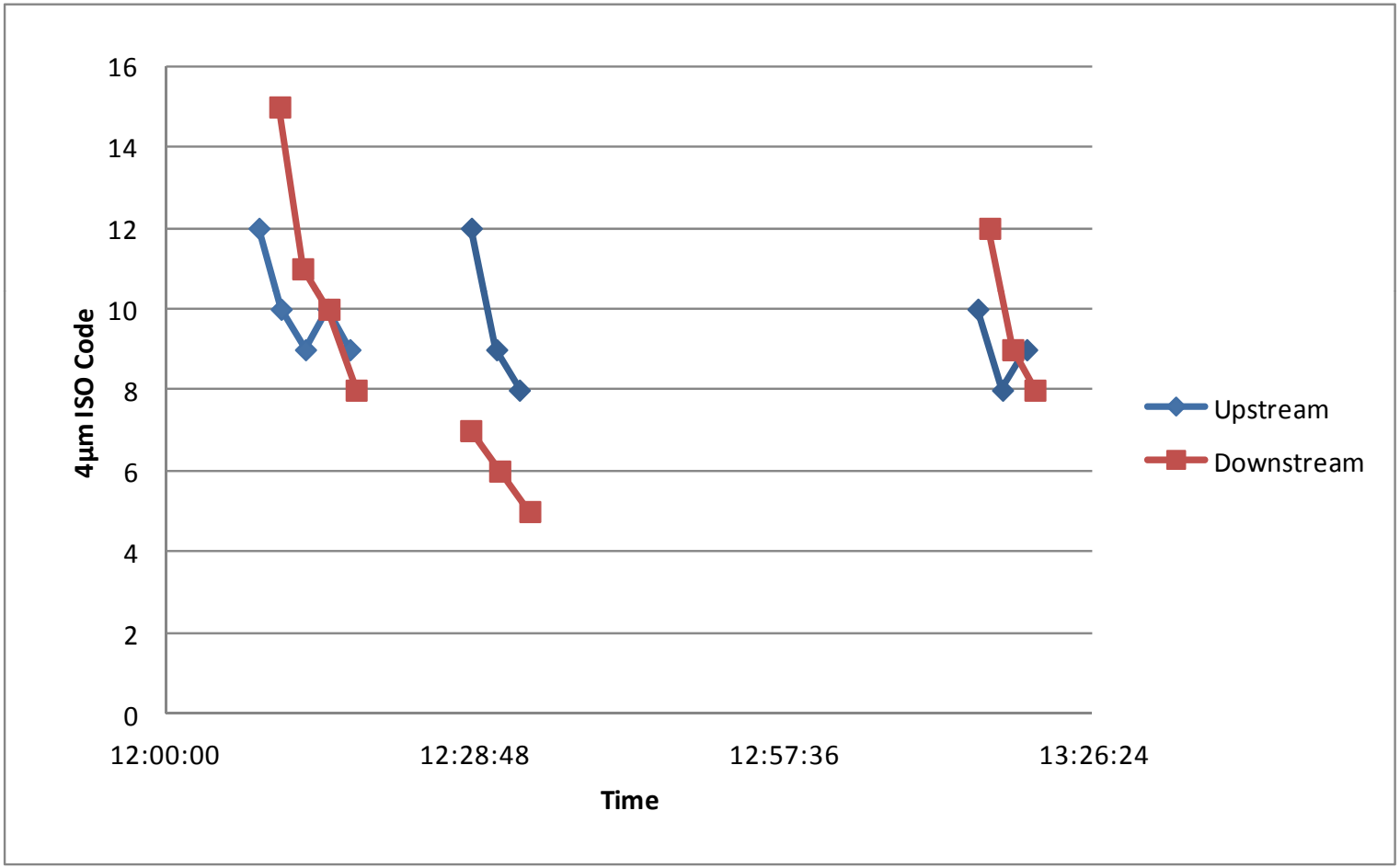
Site I – Dispensing

Date	Time (EST)	mg/L	Location	Lab ID	Avcount	ACM20 #1	ACM20 #2	S40 AVTUR #1	S40 AVTUR #2	IOS
9 Apr 2013	1310	1.13	Upstream	20	16/14/11/7	15/14/10/6	15/14/10/5	16/14/11/-	16/14/11/-	12/10/7/3
				20A	16/15/11/7	16/14/10/7	16/14/10/7	16/14/11/-	16/14/11/-	
	1310	0.40	Downstream	19	18/16/12/8	17/15/11/7	17/15/11/6	17/15/12/-	17/15/12/-	13/11/8/6
				19A	18/16/12/8	17/15/11/7	17/15/11/7	17/16/12/-	17/15/12/-	
	1330	0.30	Truck Downstream	21	15/14/11/7	15/13/9/5	15/13/10/6	15/14/10/-	15/14/10/-	10/8/5/2
				21A	16/14/11/7	15/14/10/6	15/14/10/5	16/14/11/-	16/14/11/-	
10 Apr 2013	1324	0.38	Upstream	29	16/14/11/7	15/13/10/5	15/13/10/6	15/13/10/-	15/13/11/-	
				29A	16/14/11/8	15/14/10/7	15/14/10/6	16/14/11/-	16/14/11/-	
	1324	0.00	Downstream	28	17/15/11/7	16/14/10/5	16/14/10/6	17/14/11/-	17/15/11/-	
				28A	17/15/11/7	17/14/10/7	17/14/10/7	17/15/11/-	17/15/11/-	
	1115	-	Truck Downstream	-						11/8/6/0

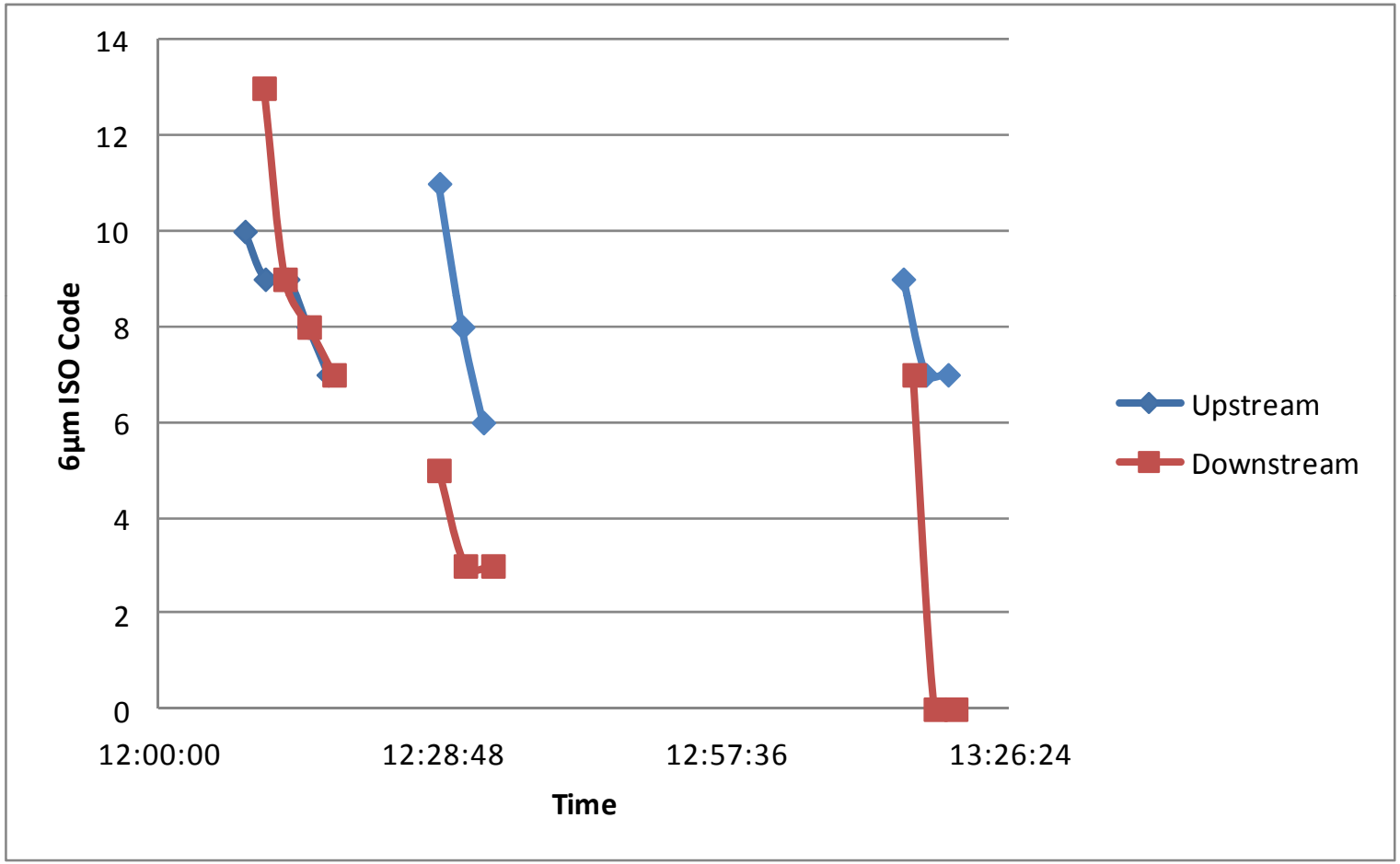
Site I – Fuel Dispensing

- Dispensing from COCO Refueling Truck into HEMTT (~4700 gallons)

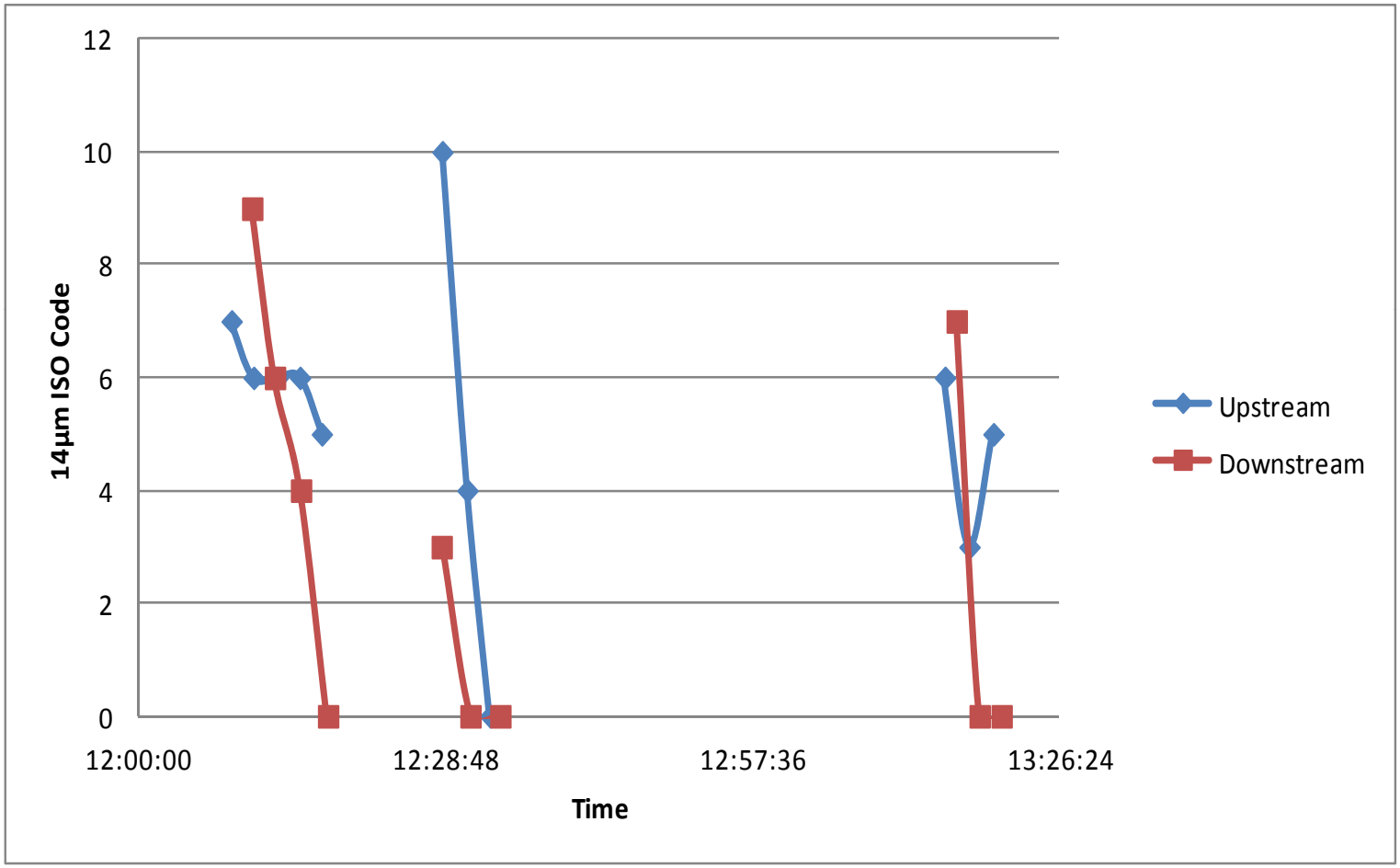
Site I – Dispensing C5 Refueling



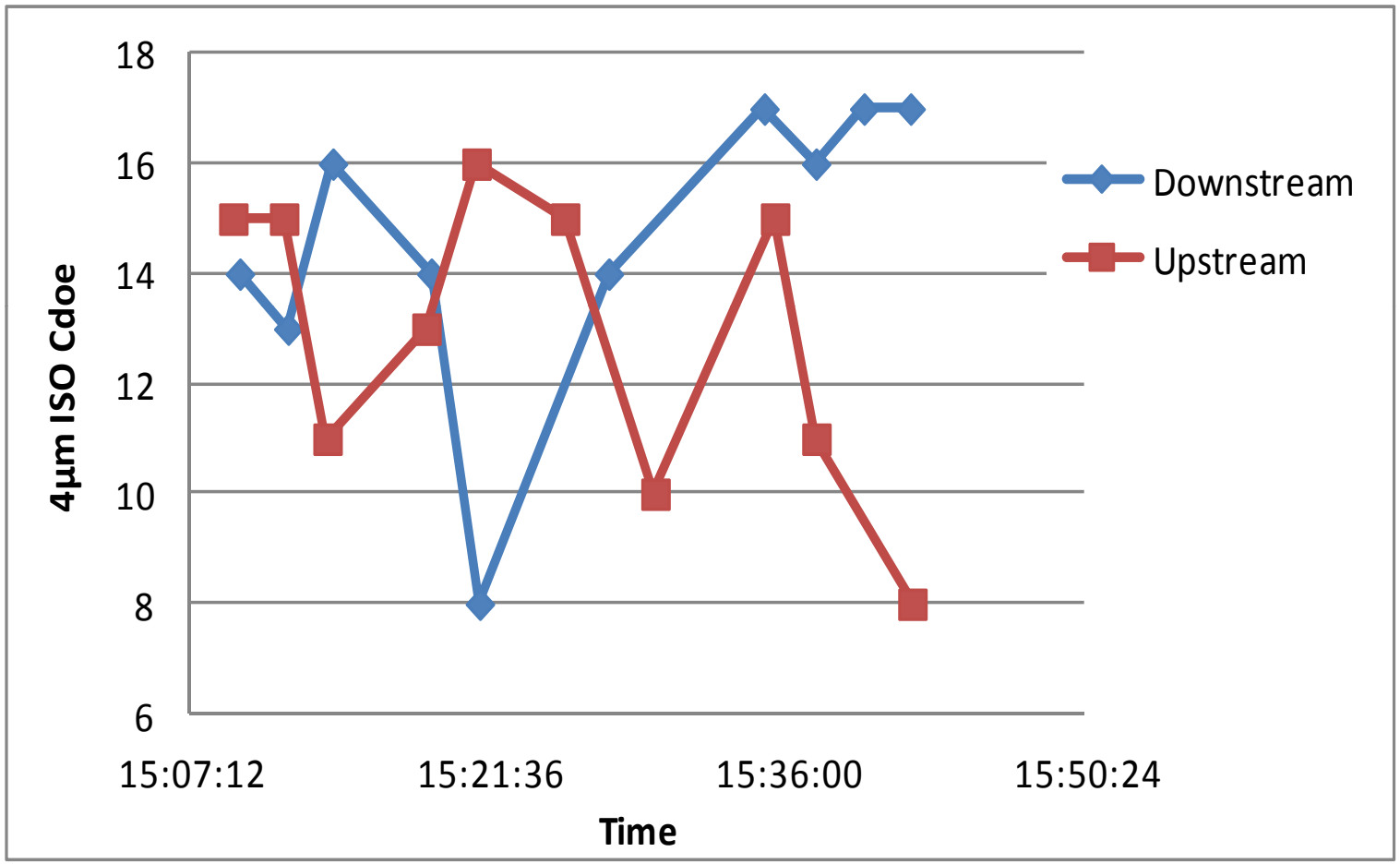
Site I – Dispensing C5 Refueling



Site I – Dispensing C5 Refueling



Site I – C17 Refueling



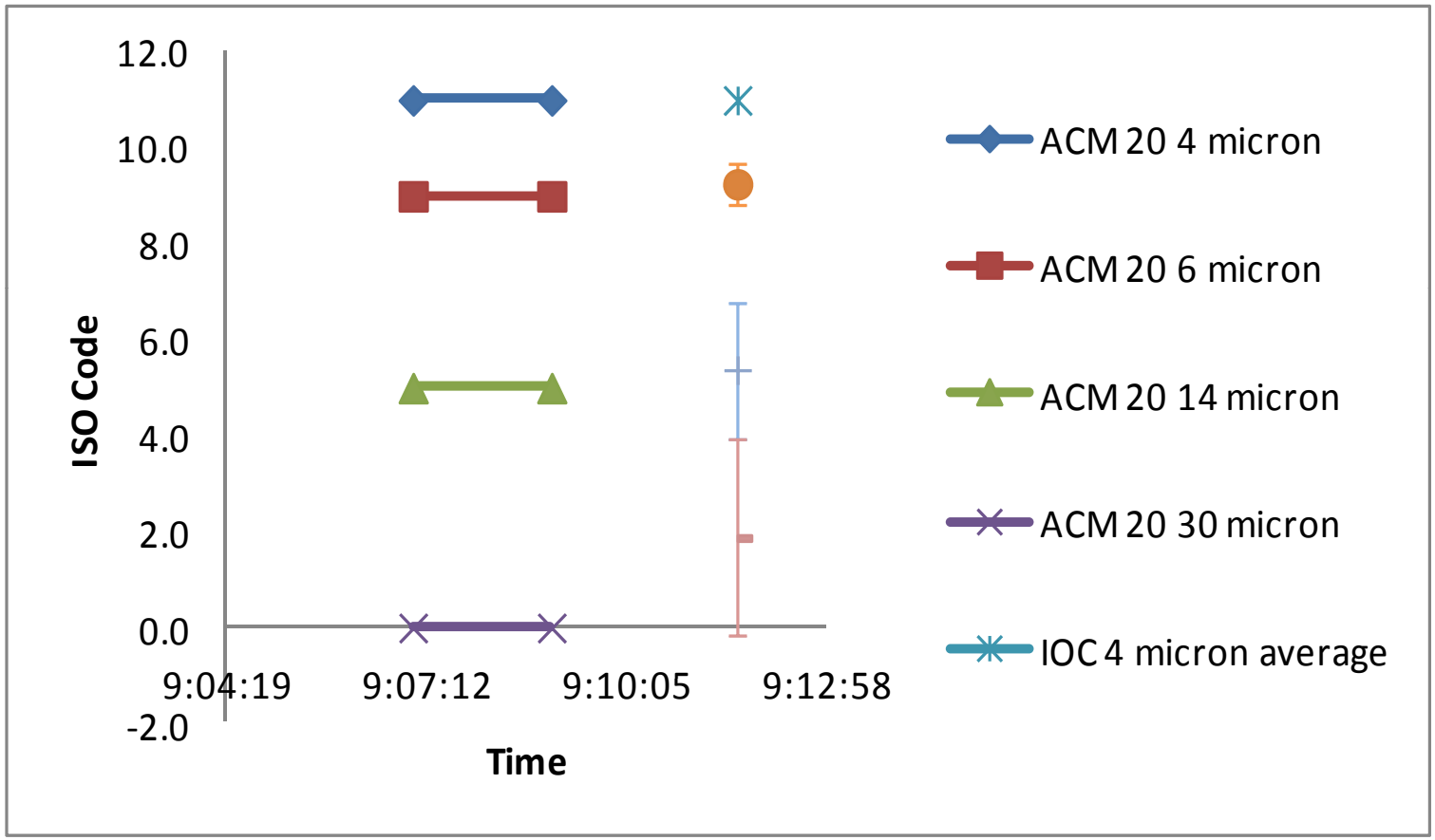
Site I – C17 Refueling

Time (EST)	mg/L	Location	Lab ID	Avcount	ACM-20 #1	ACM-20 #2	S40 AVTUR #1	S40 AVTUR #2
1511	0.70	Upstream	31	16/14/10/7	16/13/10/7	16/13/10/6	16/14/10/-	16/14/10/-
			31A	17/14/11/7	16/14/10/6	16/14/10/6	16/14/11/-	16/14/10/-
1511	0.25	Downstream	30	16/14/11/7	15/13/10/6	15/13/10/5	16/14/10/-	16/14/11/-
			30A	16/14/11/7	16/14/10/6	16/14/10/6	16/14/11/-	16/14/11/-

Site I - ACM 20 Verification

- Tested a lab based unit in the field
- ACM20 was designed for online but outside the scope of this evaluation
- Compared the data between the ACM20 and the IOS (upstream)

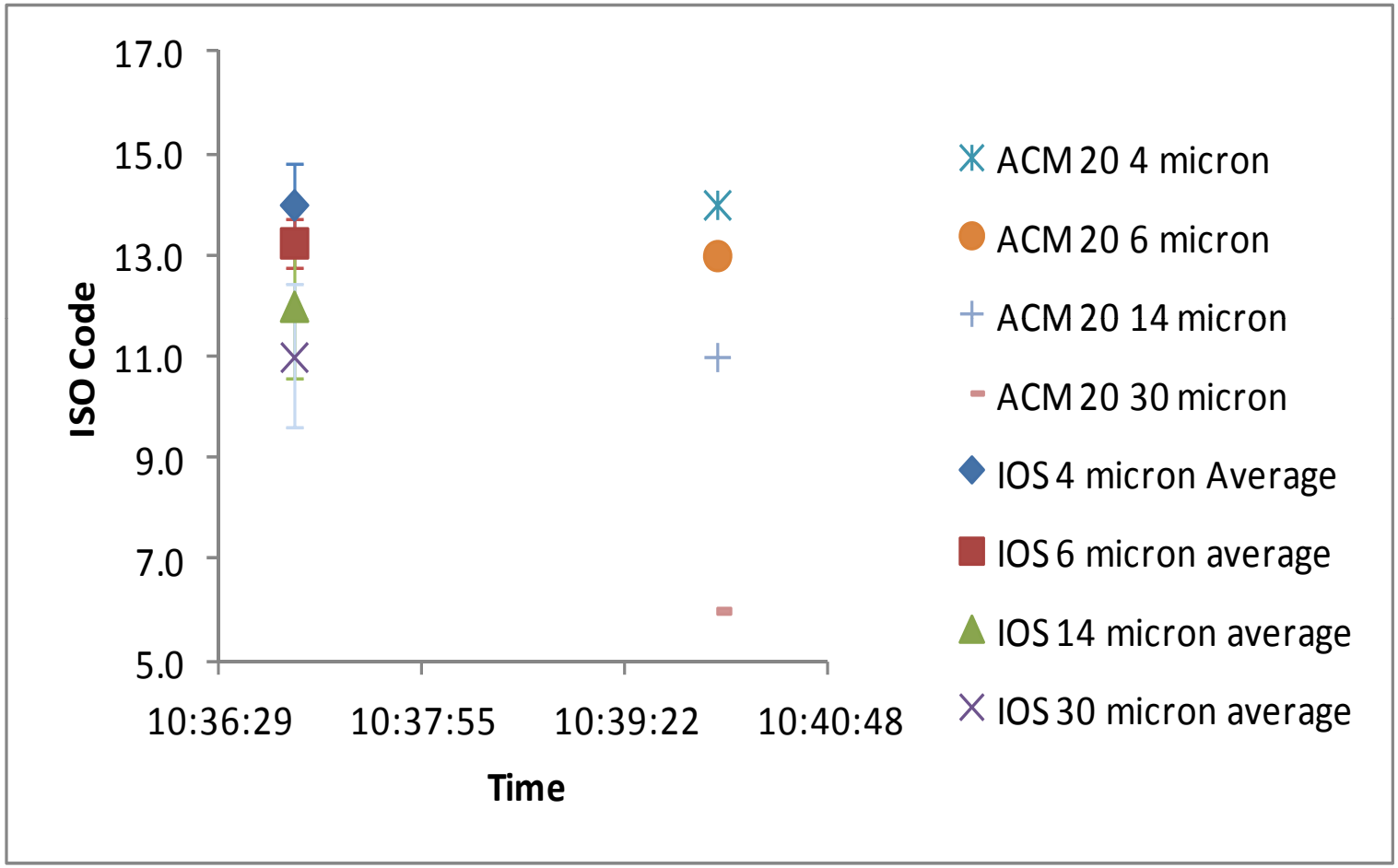
Site I - ACM 20 Verification



Site I - ACM 20 Verification

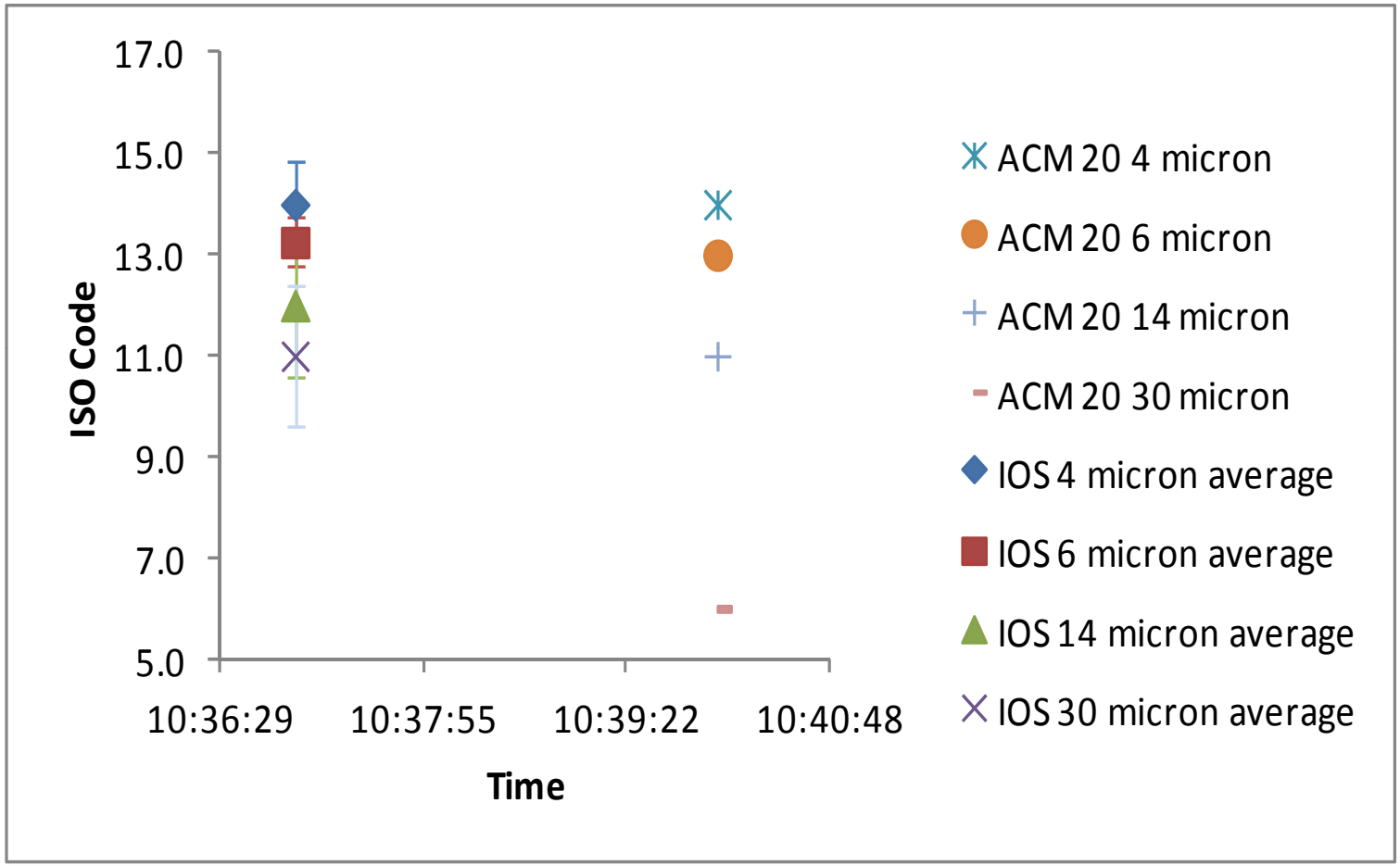
Time (EST)	Location	Lab ID	Avcount	ACM20 On-line	ACM20 #1	ACM20 #2	S40 AVTUR #1	S40 AVTUR #2
845	Upstream	32	17/15/11/7		15/13/9/5	15/13/9/5	16/14/10/-	16/14/10/-
		32A	17/15/11/7		16/14/10/6	16/14/10/6	16/14/11/-	16/14/11/-
900	Upstream	33	16/14/10/7		16/14/10/0	16/14/10/4	17/14/11/-	17/14/11/-
		33A	17/15/11/8		16/14/10/5	17/14/10/5	17/15/11/-	17/15/11/-
907	Upstream			11/9/5/0				
909	Upstream			11/9/5/0				

Site I - Bulk Sampling
ACM 20 Verification



Site I - Bulk Sampling
ACM 20 Verification

Unclassified

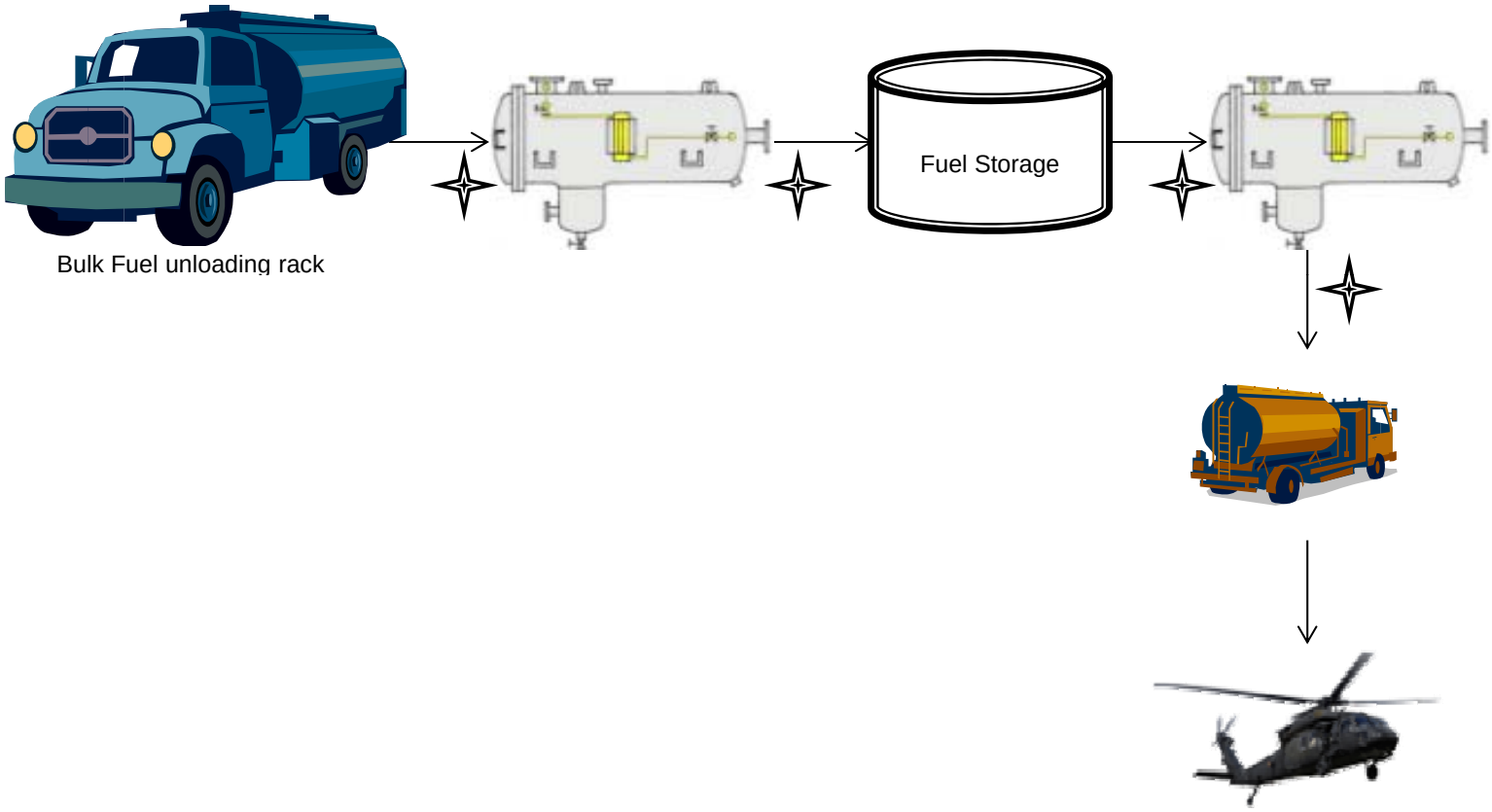


Site I - Bulk Sampling ACM 20 Verification

TARDEC

Time (EST)	Truck	Location	Lab Unit Run ID	Avcount	ACM-20 On-line	ACM-20 #1	ACM-20 #2	S40 AVTUR #1	S40 AVTUR #2
1014	6	Bulk	35	16/14/11/9	14/13/11/6	16/13/11/10	16/13/10/8	16/14/12/-	16/14/11/-
			35A	17/14/12/11		16/14/12/12	16/14/12/11	16/14/13/-	16/15/13/-
1030	7	Bulk	36	17/14/11/9	12/11/6/6	16/14/10/6	16/14/10/6	16/14/11/-	16/14/11/-
			36A	17/15/11/9		16/14/10/6	16/14/10/6	17/15/11/-	17/14/11/-

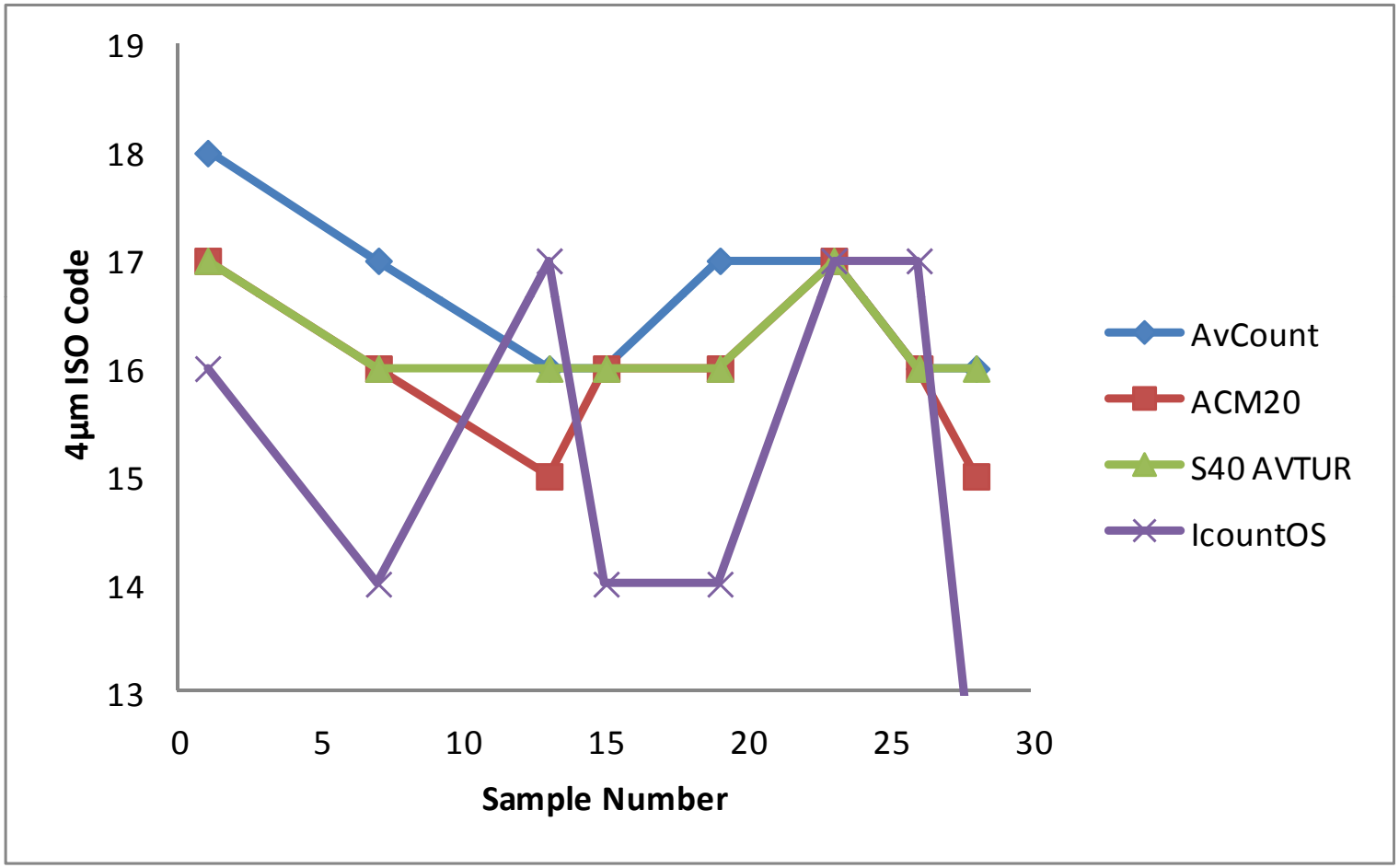
Site II – Fuel Distribution Overview



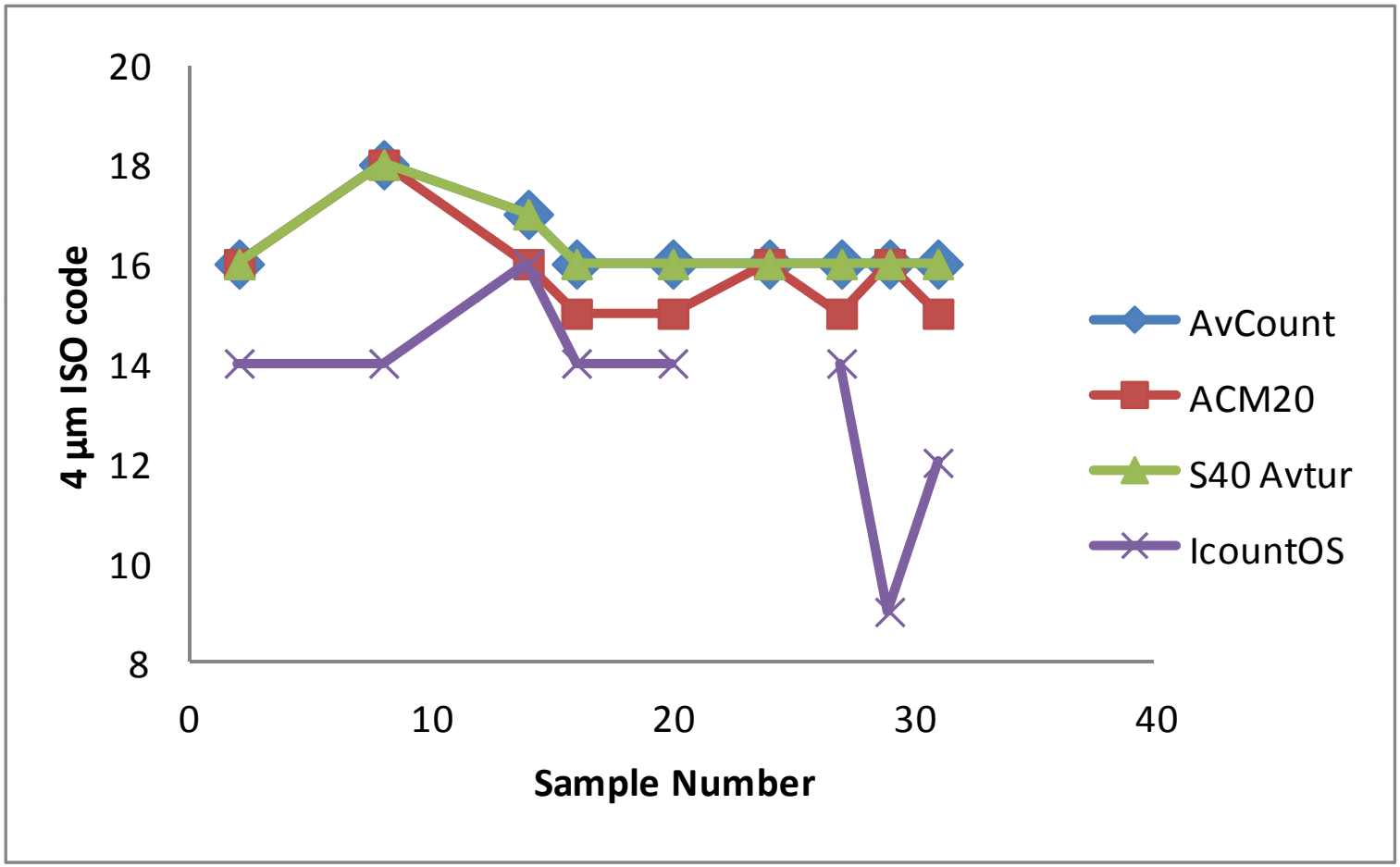
Site II - Samples

Sample #	Date	Time (EST)	Sample Source/Location	Sample #	Date	Time (EST)	Sample Source/Location
1	15-Apr-2013	930	Location A AHP Reciept upstream	19	16-Apr-2013	1300	Location A AHP Reciept upstream
2	15-Apr-2013	930	Location A AHP Reciept downstream	20	16-Apr-2013	1300	Location A AHP Reciept downstream
3	15-Apr-2013	1340	Location A AHP Issue upstream	21	17-Apr-2013	915	Location B AHP air pad 11
4	15-Apr-2013	1300	Location A AHP Issue downstream	22	17-Apr-2013	938	Location B AHP air pad 11
5	15-Apr-2013	1300	Location A AHP Issue upstream	23	17-Apr-2013	1330	Location C AHP Reciept upstream
6	15-Apr-2013	1340	Location A AHP Issue downstream	24	17-Apr-2013	1330	Location C AHP Reciept downstream
7	15-Apr-2013	1400	Location A AHP Reciept upstream	25	17-Apr-2013	1408	Location C AHP issue upstream
8	15-Apr-2013	1400	Location A AHP Reciept downstream	26	18-Apr-2013	840	Location C AHP Reciept upstream
9	15-Apr-2013	1435	Location A AHP Issue upstream	27	18-Apr-2013	840	Location C AHP Reciept downstream
10	15-Apr-2013	1435	Location A AHP Issue downstream	28	18-Apr-2013	930	Location C AHP Reciept upstream
11	15-Apr-2013	1355	Location A AHP Issue upstream	29	18-Apr-2013	930	Location C AHP Reciept downstream
12	15-Apr-2013	1355	Location A AHP Issue downstream	30	18-Apr-2013	1347	Location C AHP Reciept upstream
13	16-Apr-2013	800	Location A AHP Reciept upstream	31	18-Apr-2013	1347	Location C AHP Reciept downstream
14	16-Apr-2013	800	Location A AHP Reciept downstream	32	18-Apr-2013	1320	Location C AHP Issue upstream
15	16-Apr-2013	930	Location A AHP Reciept upstream	33	18-Apr-2013	1320	Location C AHP Issue downstream
16	16-Apr-2013	930	Location A AHP Reciept downstream	34	18-Apr-2013	1320	Location C AHP Issue upstream
17	16-Apr-2013	1300	Location A AHP Issue upstream	35	18-Apr-2013	1320	Location C AHP Issue downstream
18	16-Apr-2013	1300	Location A AHP Issue downstream				

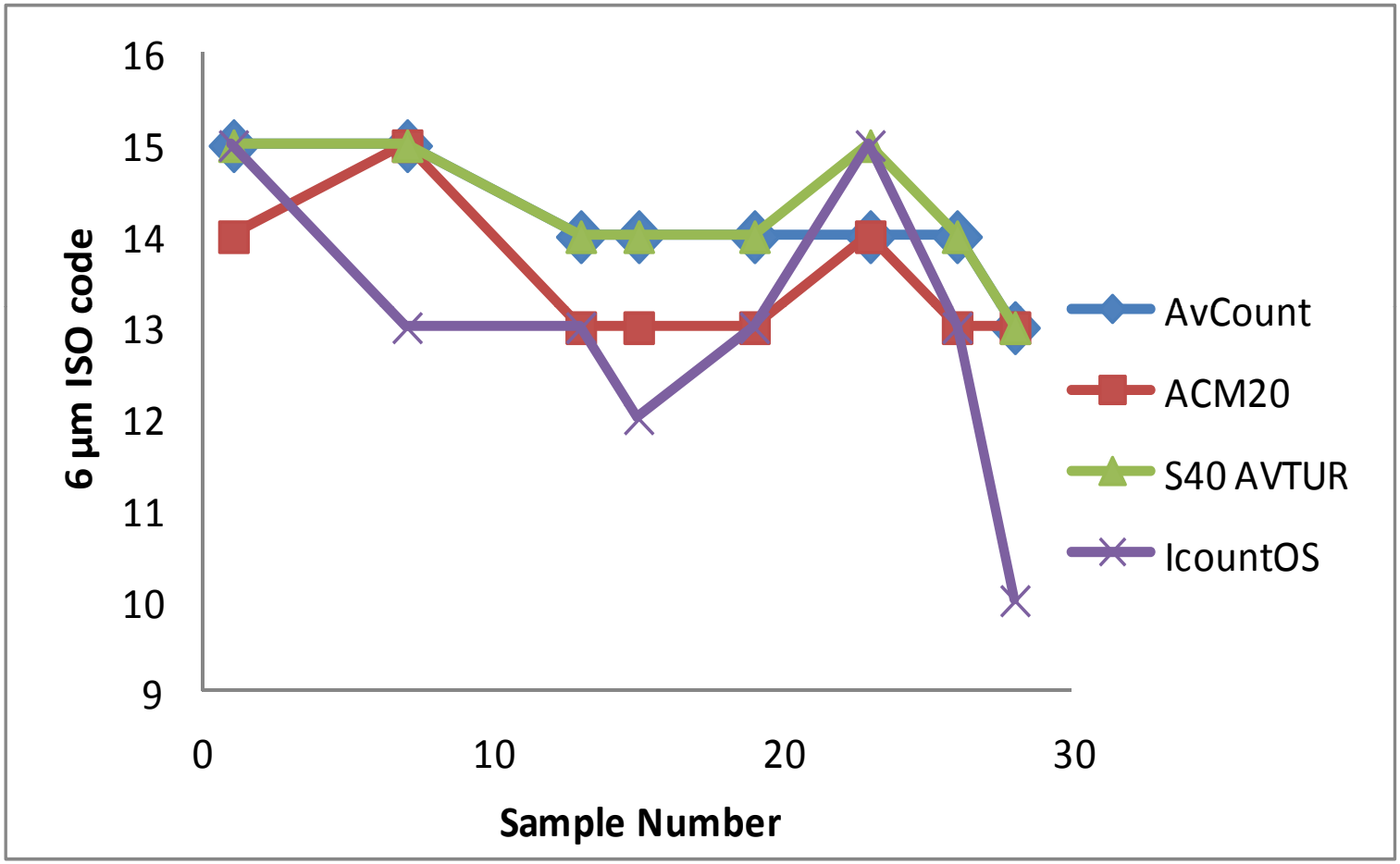
Site II - Receipts Upstream



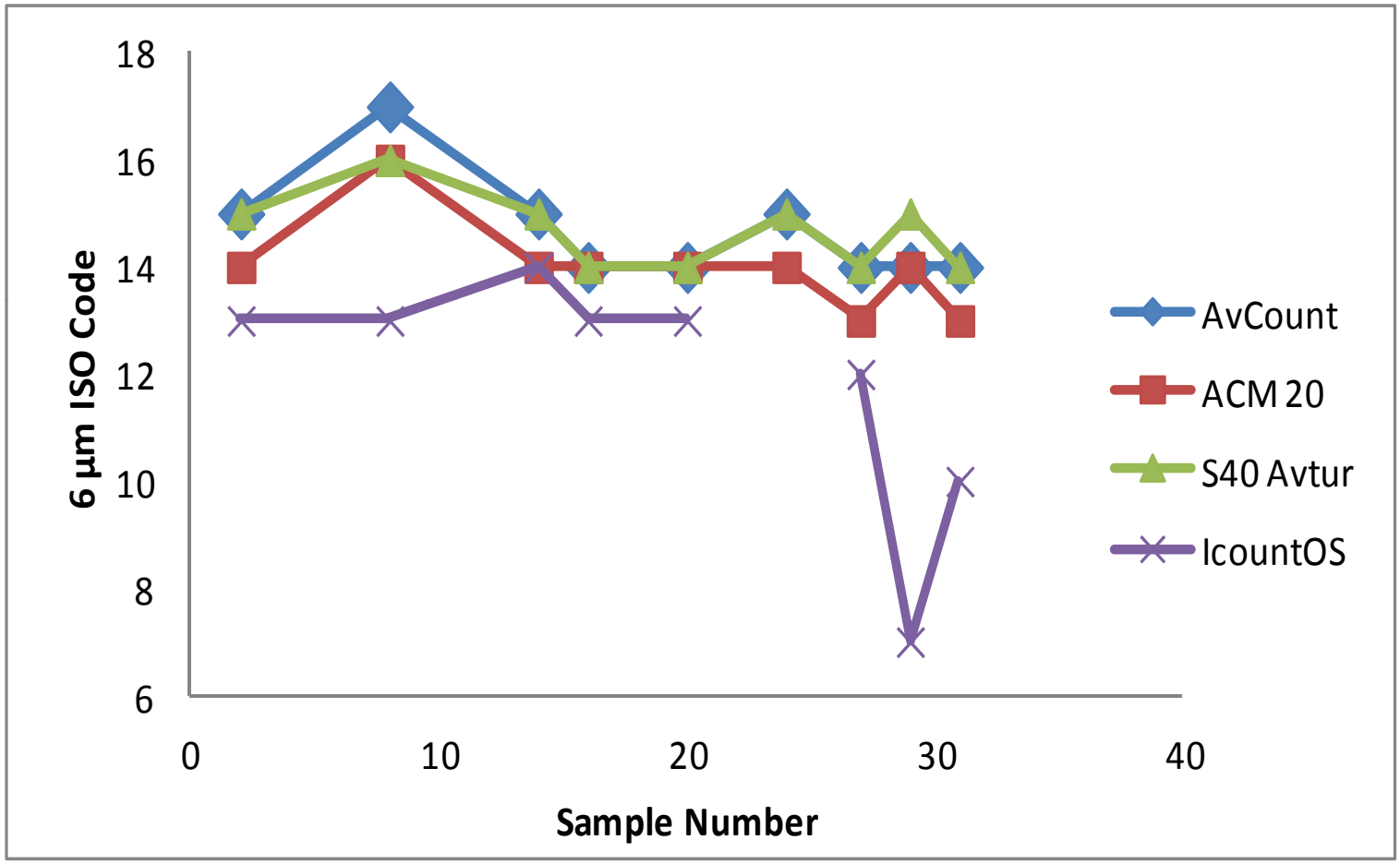
Site II - Receipts Downstream



Site II - Receipts Upstream



Site II - Receipts Downstream



Site II - Receipts

Time (EST)	*Location*	Sample #	mg/L	Avcount	ACM20	S40 AVTUR	IcountOS
930	upstream	1	0.3	18/15/11/8	17/14/10/6	17/15/11/-	16/15/14/13
930	downstream	2	0.2	16/15/12/9	16/14/11/7	16/15/12/-	14/13/11/7
1400	upstream	7	0.0	17/15/12/10	16/15/12/8	16/15/12/-	14/13/10/9
1400	downstream	8	1.0	18/17/14/10	18/16/13/8	18/16/13/-	14/13/9/6
800	upstream	13	0.8	16/14/10/6	15/13/9/4	16/14/10/-	17/13/9/6
800	downstream	14	0.5	17/15/11/8	16/14/10/6	17/15/11/-	16/14/10/7
930	upstream	15	0.0	16/14/10/7	16/13/10/5	16/14/10/-	14/12/9/6
930	downstream	16	0.0	16/14/11/7	15/14/10/5	16/14/11/-	14/13/9/7
1300	upstream	19	1.0	17/14/11/8	16/13/10/5	16/14/11/-	14/13/11/10
1300	downstream	20	1.7	16/14/11/7	15/14/10/5	16/14/11/-	14/13/10/8
1330	upstream	23	0.7	17/14/11/7	17/14/11/7	17/15/12/-	17/15/13/10
1330	downstream	24	0.4	16/15/11/7	16/14/10/5	16/15/11/-	-
840	upstream	26	1.0	16/14/10/6	16/13/9/4	16/14/10/-	17/13/10/6
840	downstream	27	0.4	16/14/11/7	15/13/10/7	16/14/10/-	14/12/9/7
930	upstream	28	0.1	16/13/9/6	15/13/8/4	16/13/9/-	12/10/6/0
930	downstream	29	0.1	16/14/10/6	16/14/11/9	16/15/11/-	9/7/0/0

Site II – Location A

Filter Separator Systems

Refueling
Issuing FS; 1 for each stand

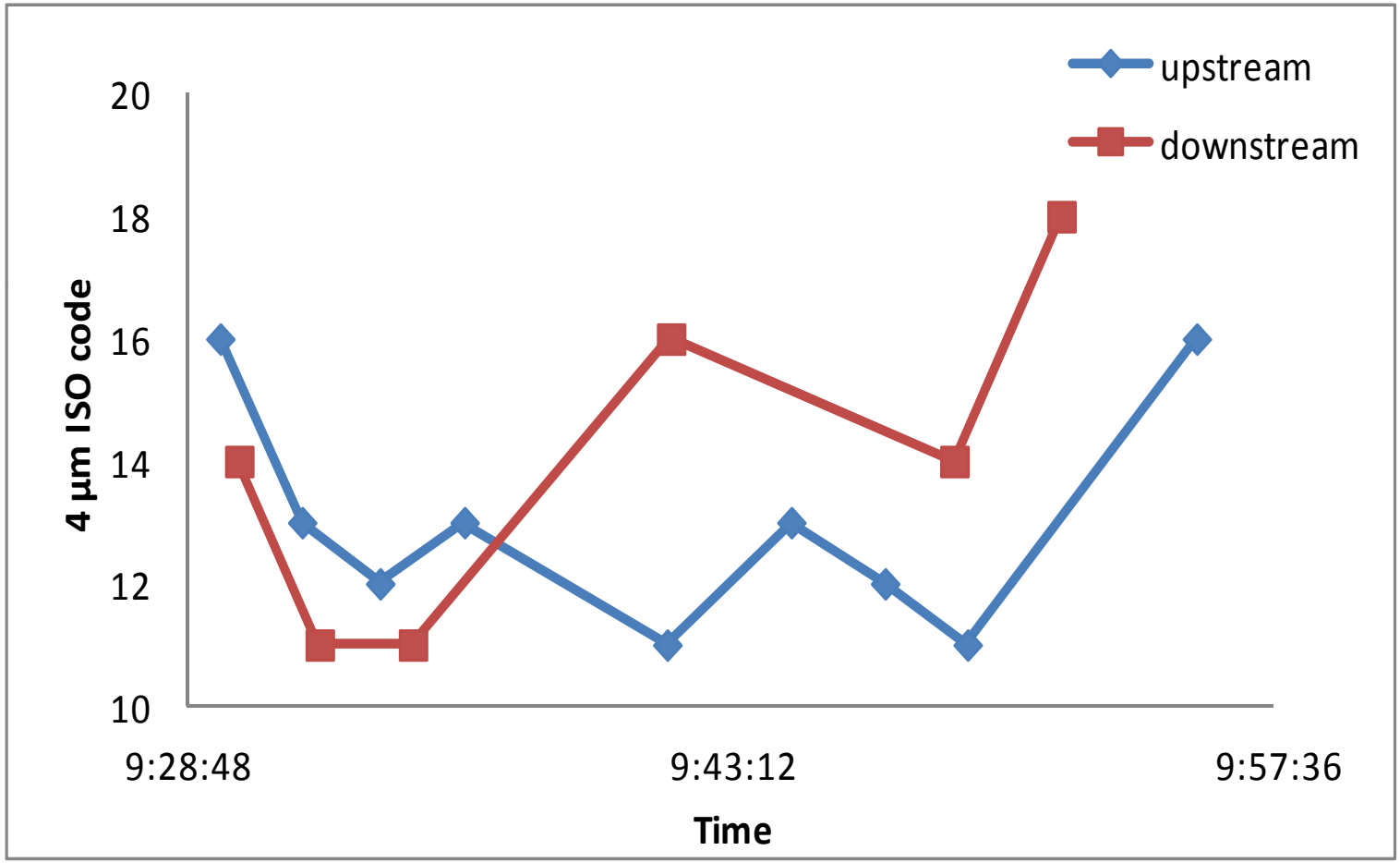
Bulk Delivery
Receipt FS; 1 for each stand

Site II – Location A

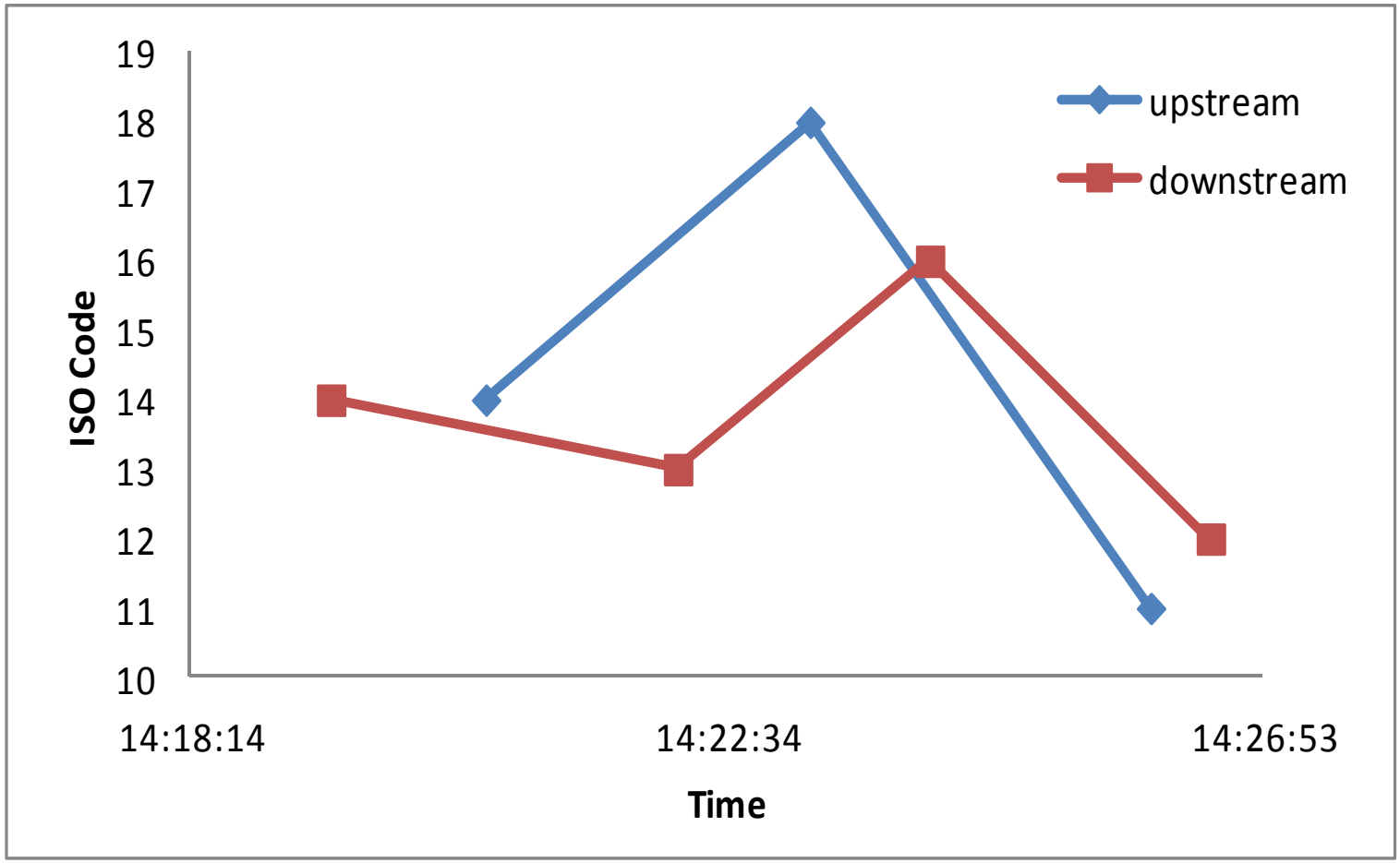
- Samples taken upstream and downstream of the Filter Separator
  - ✓ IOS (online)
  - ✓ Matched weight monitor
  - ✓ Aqua-Glo

- Refueling trucks were small (~2500gals) and would fill before we could pull gravimetrics and Aqua-Glo samples

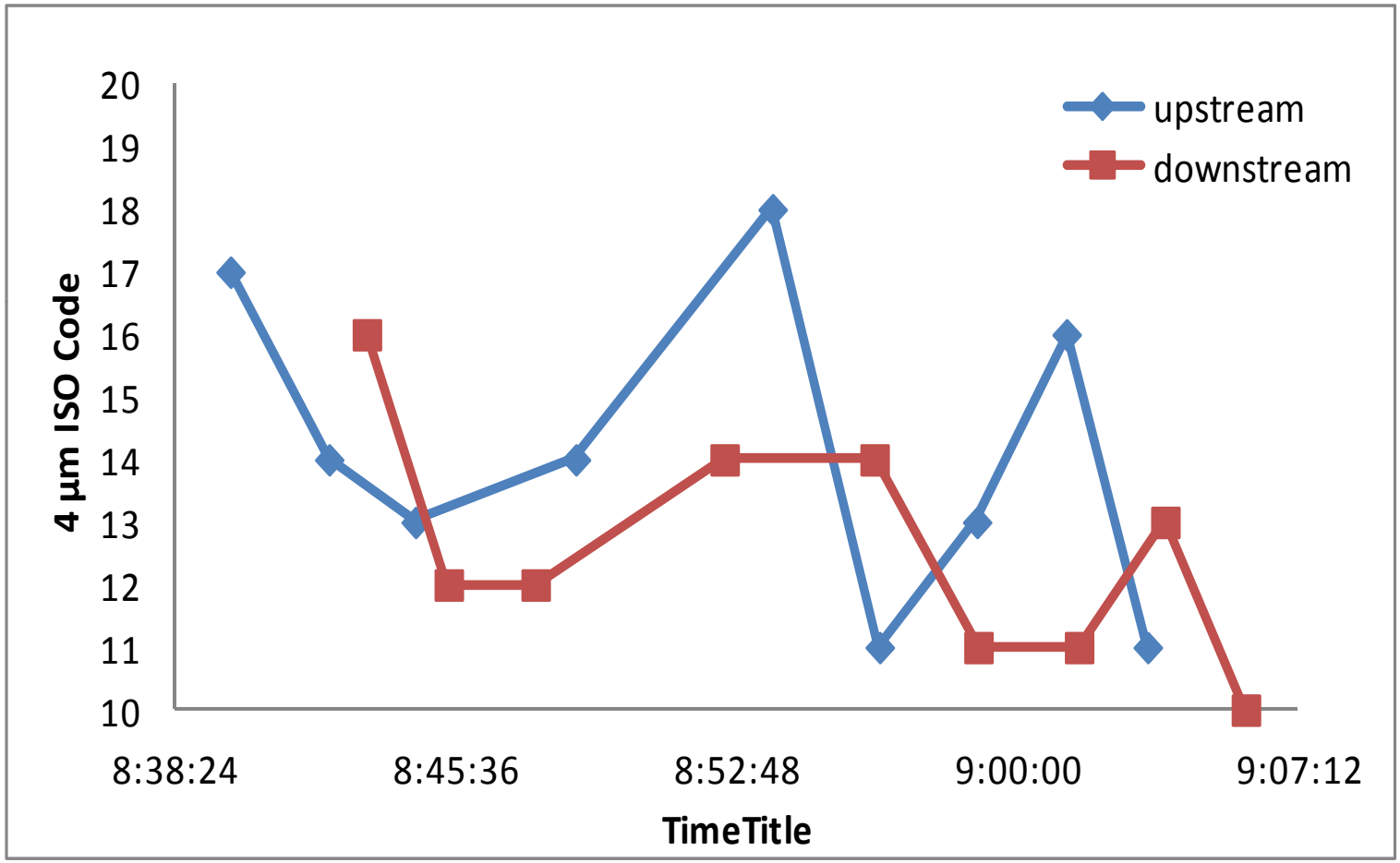
Site II – Location A – Samples 1 & 2



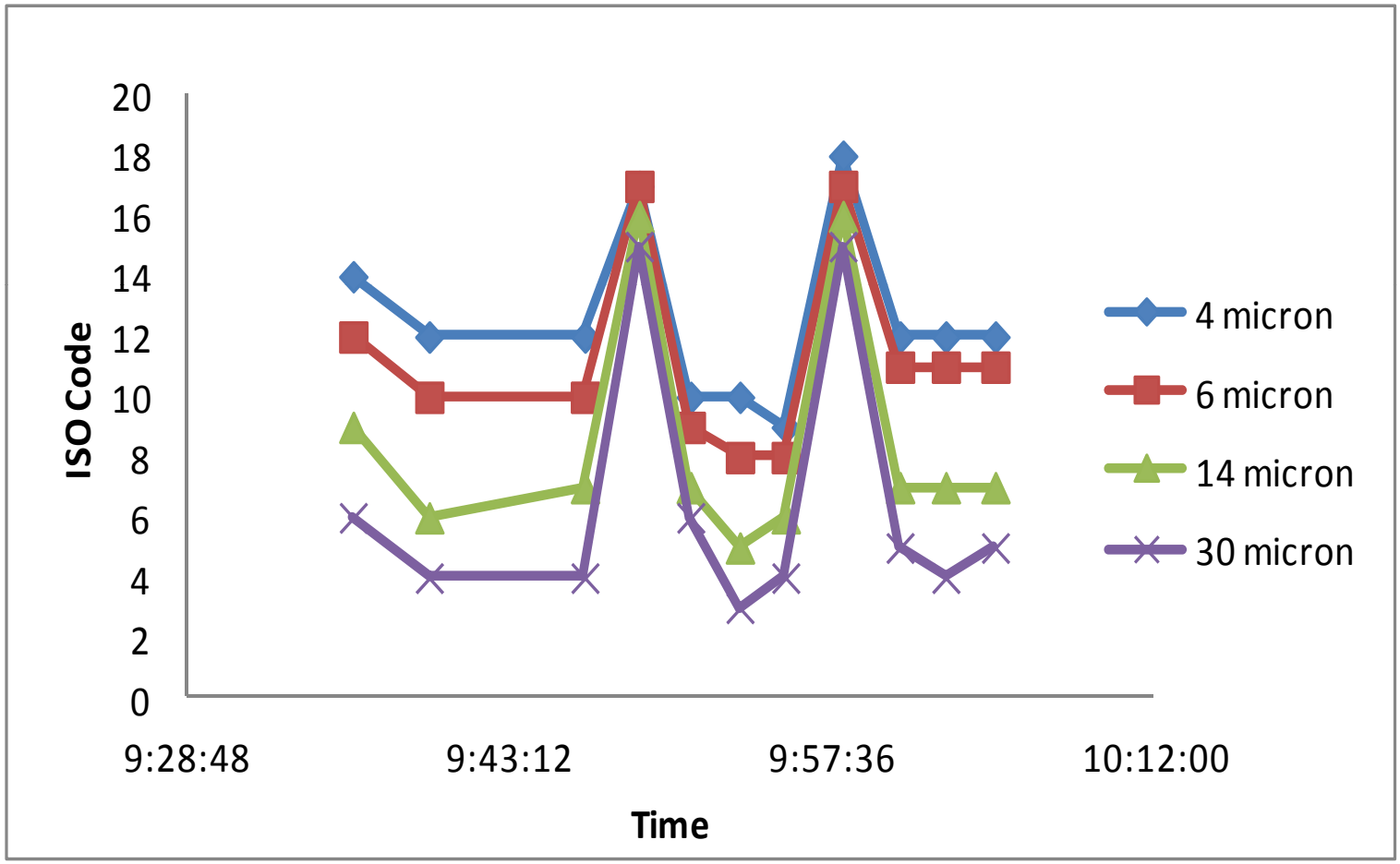
Site II – Location A – Samples 7 & 8



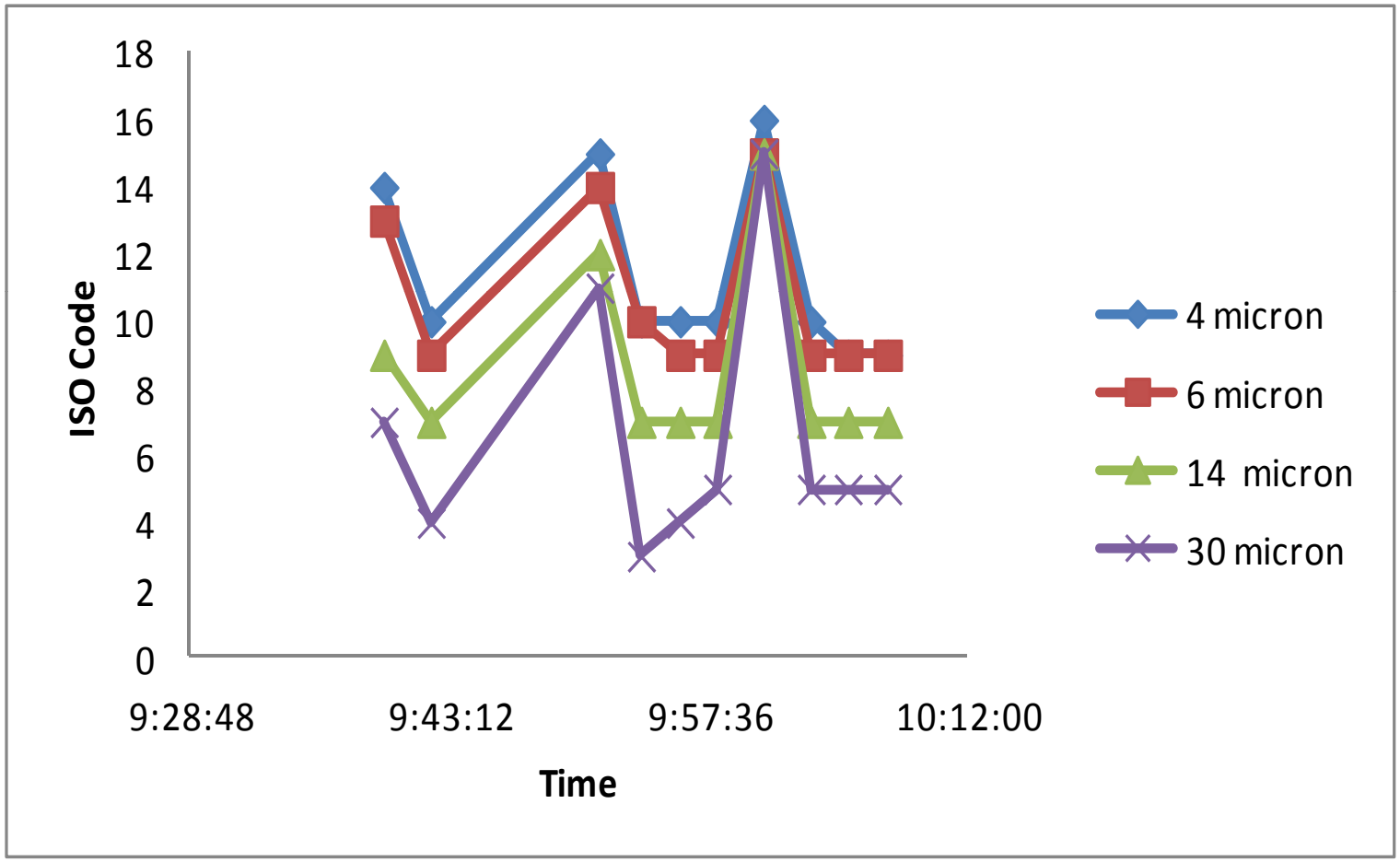
Site II – Location A – Samples 13 & 14



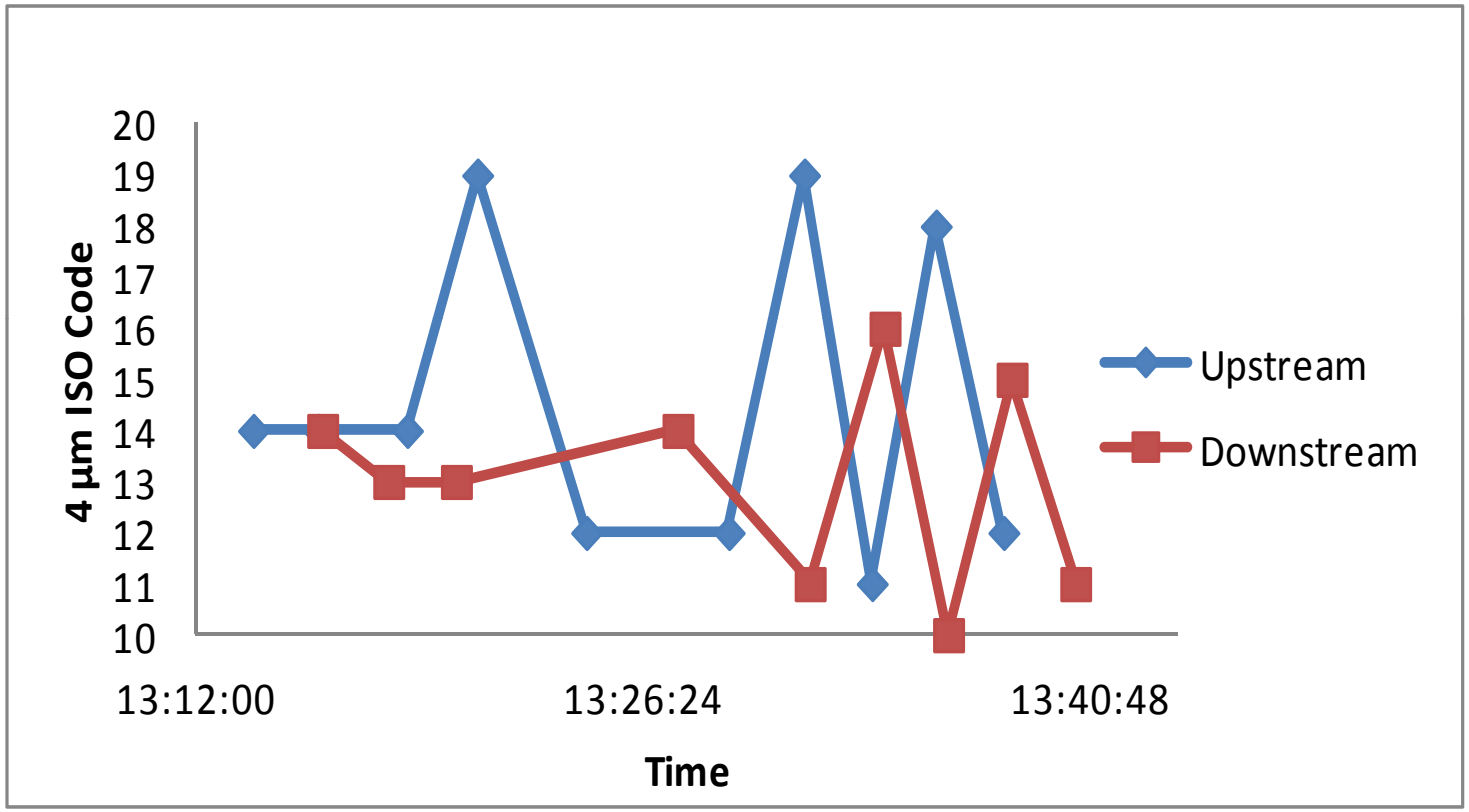
Site II – Location A – Sample 15



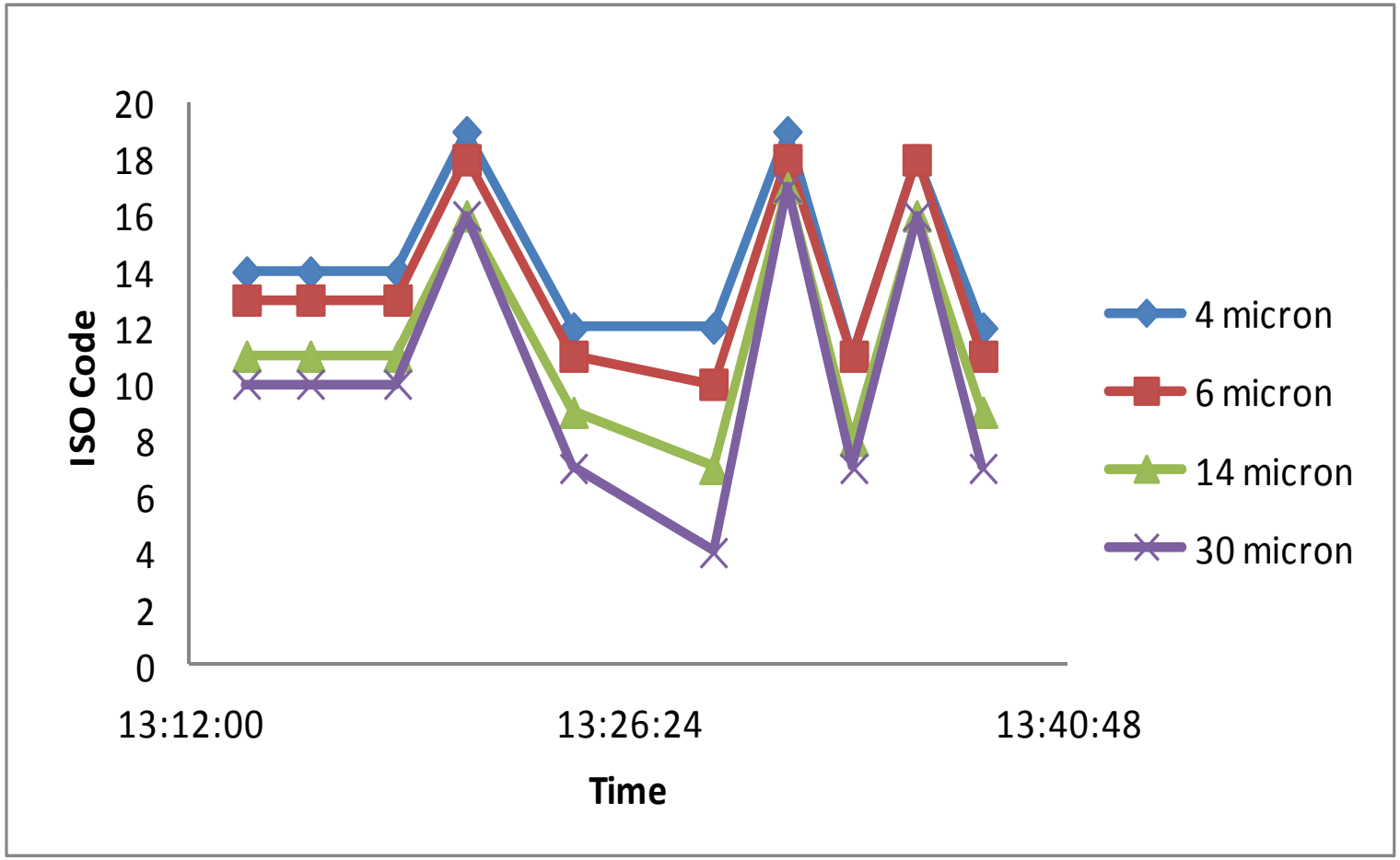
Site II – Location A – Sample 16



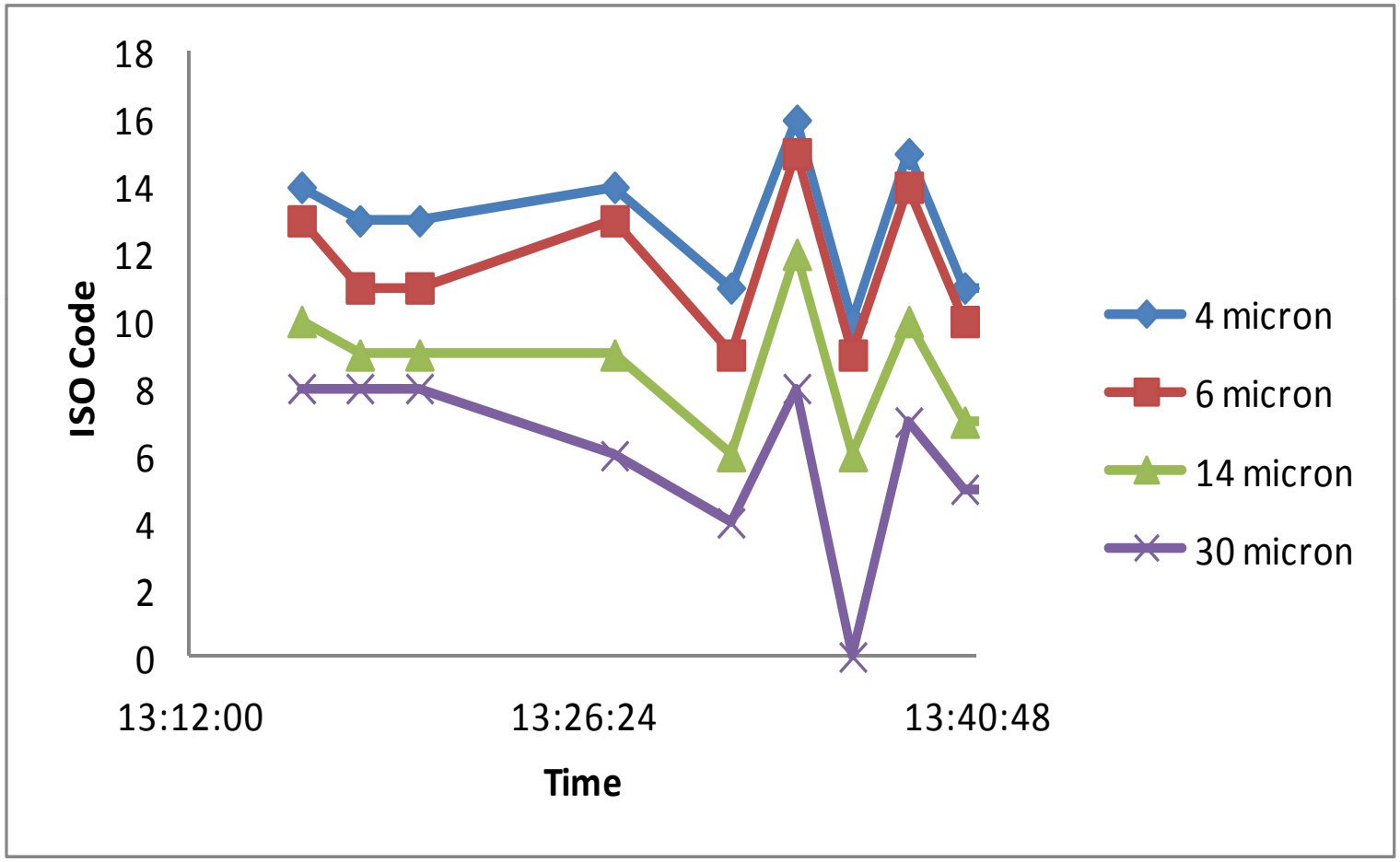
Site II – Location A – Samples 19 & 20



Site II – Location A – Sample 19



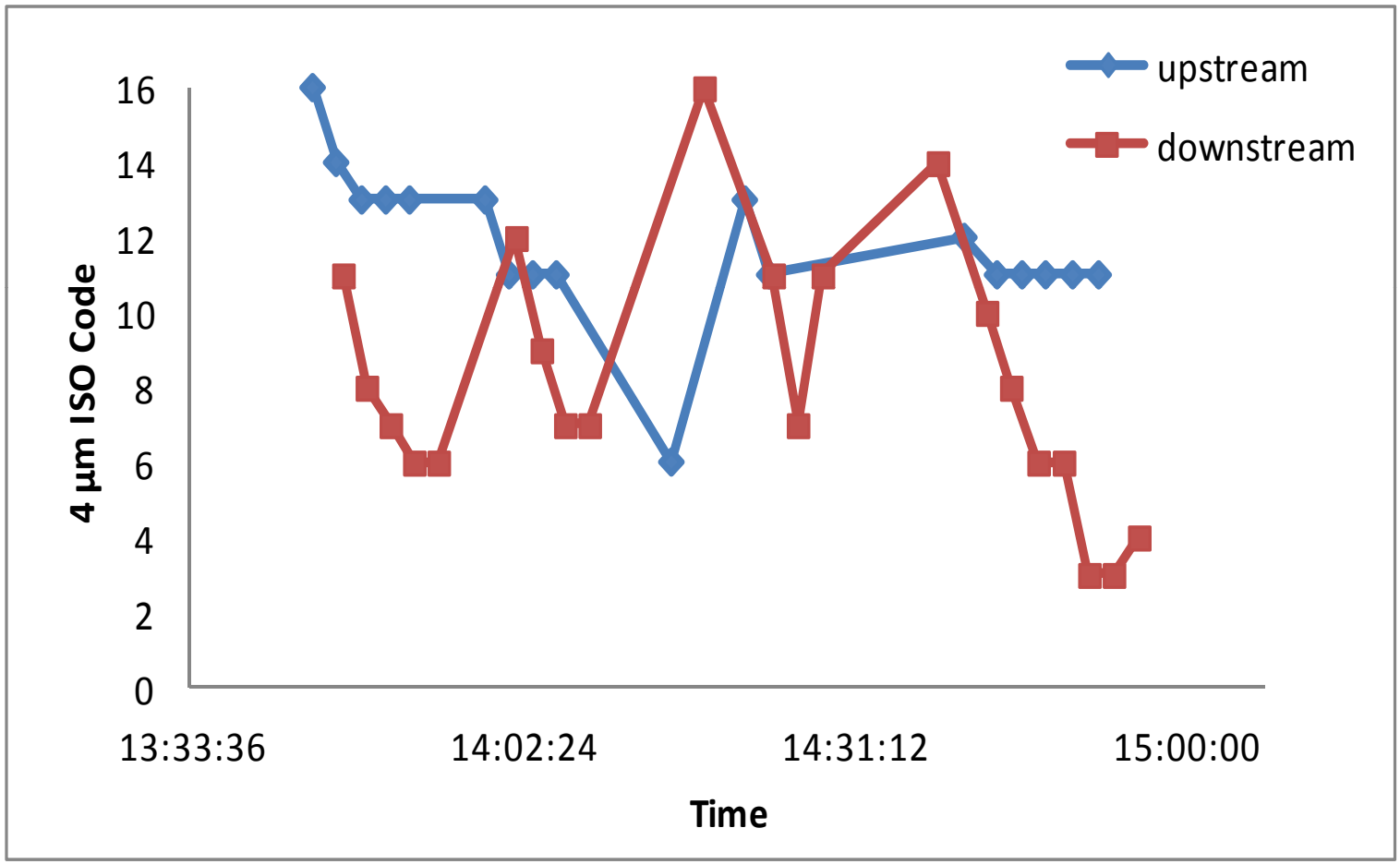
Site II – Location A – Sample 20



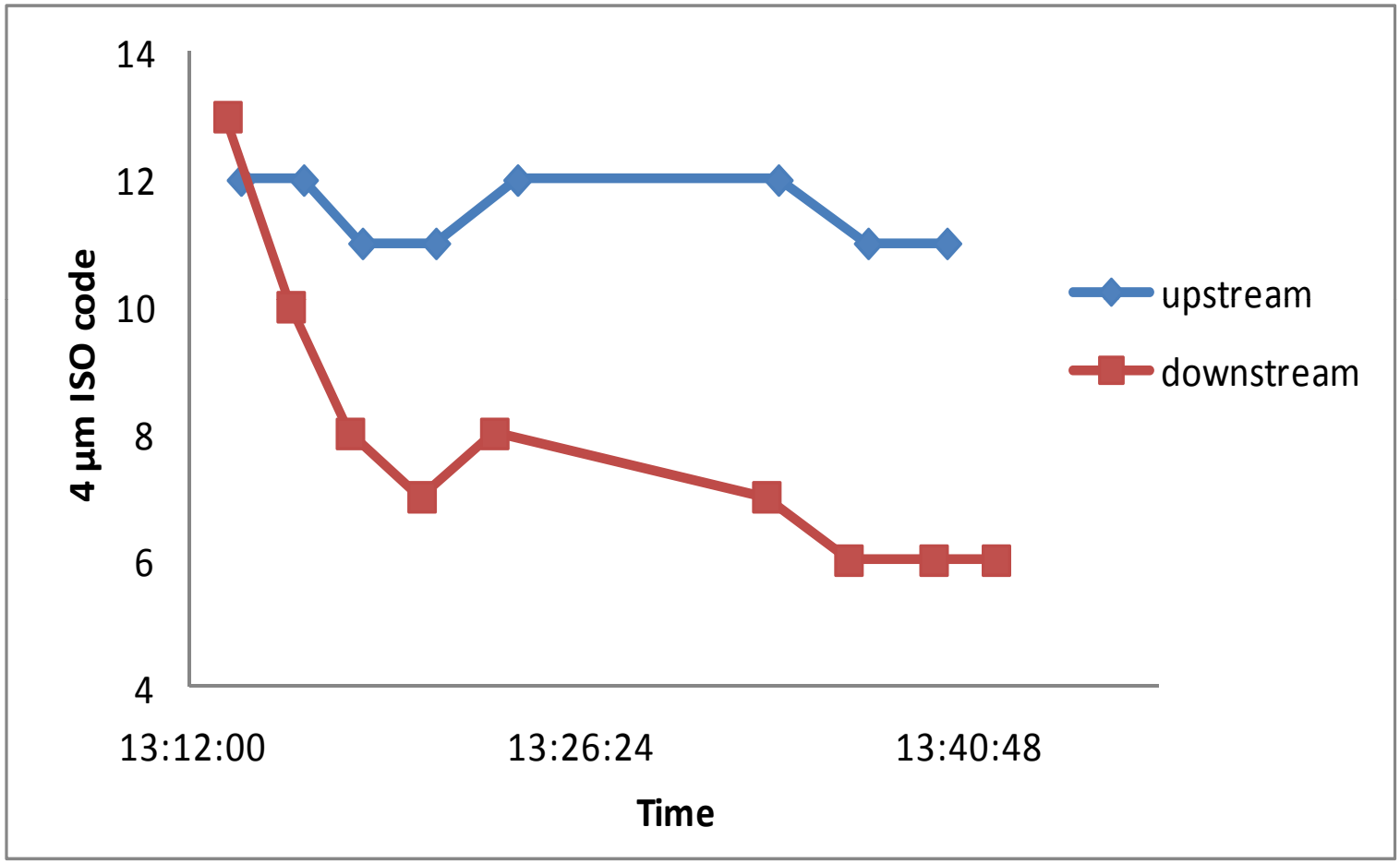
In-line testing Observation

IOS counts would spike during bulk offload. These trucks were baffled and air was introduced to the system when the operators switched tank compartments.

Site II – Location A – Issue 2,4,5,6,11 & 12



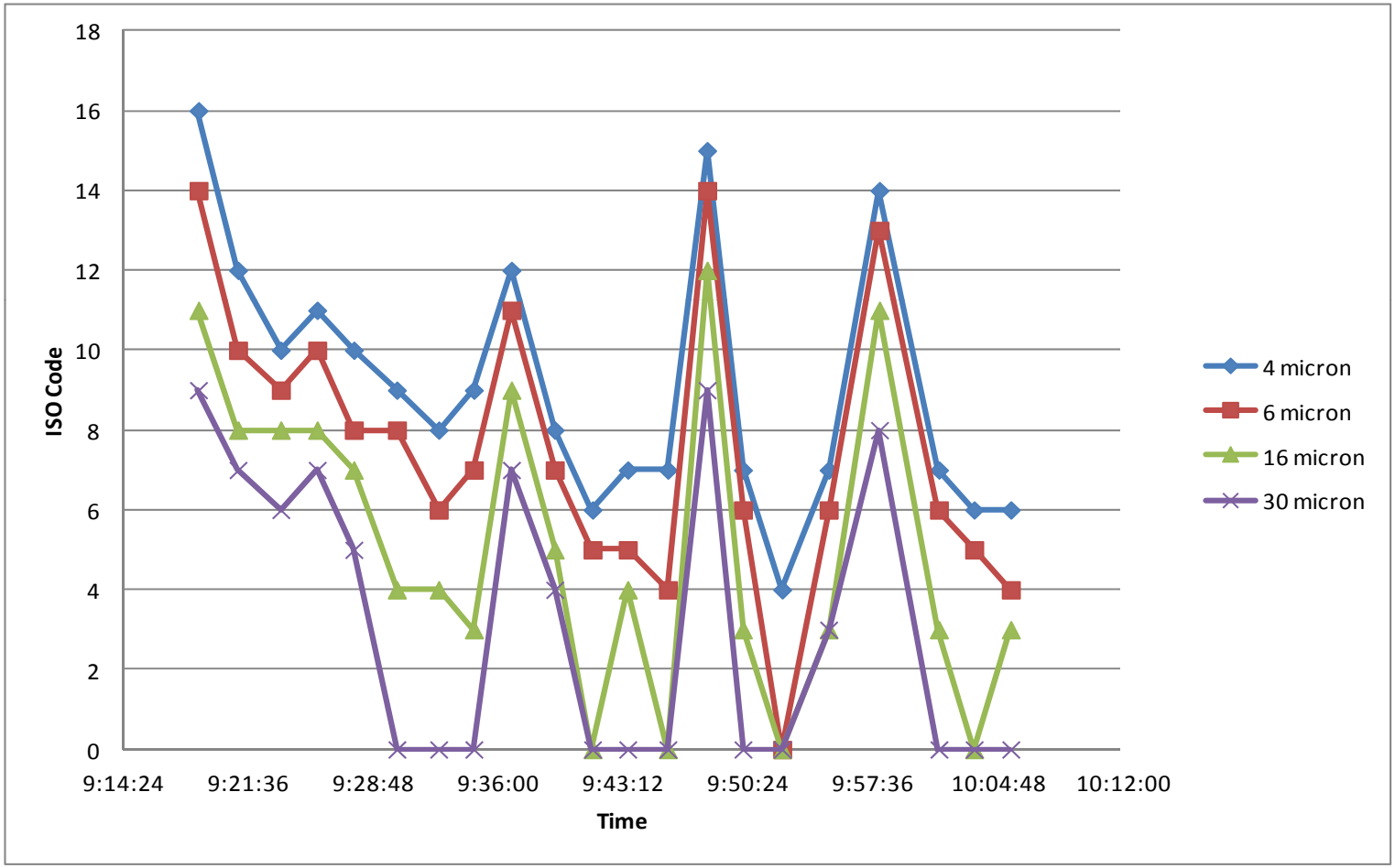
Site II – Location A – Issue 17 & 18



Site II – Location B - Army Heliport

- Hot refueling location
- 2 bulk tanks; 2 receiving FS
- Fuel that isn't issued is refiltered through system
- Typical refuel takes 2-4 minutes

Site II – Location B - Air Pad 11



Site II – Location B - Air Pad 11

Time (EST)	Sample #	Avcount	ACM20	S40 AVTUR
915	21	16/14/11/7	16/14/10/6	17/14/11/-
938	22	16/14/10/7	15/13/9/6	16/13/10/-

Site II – Location C
Bulk Delivery and Refueling Station

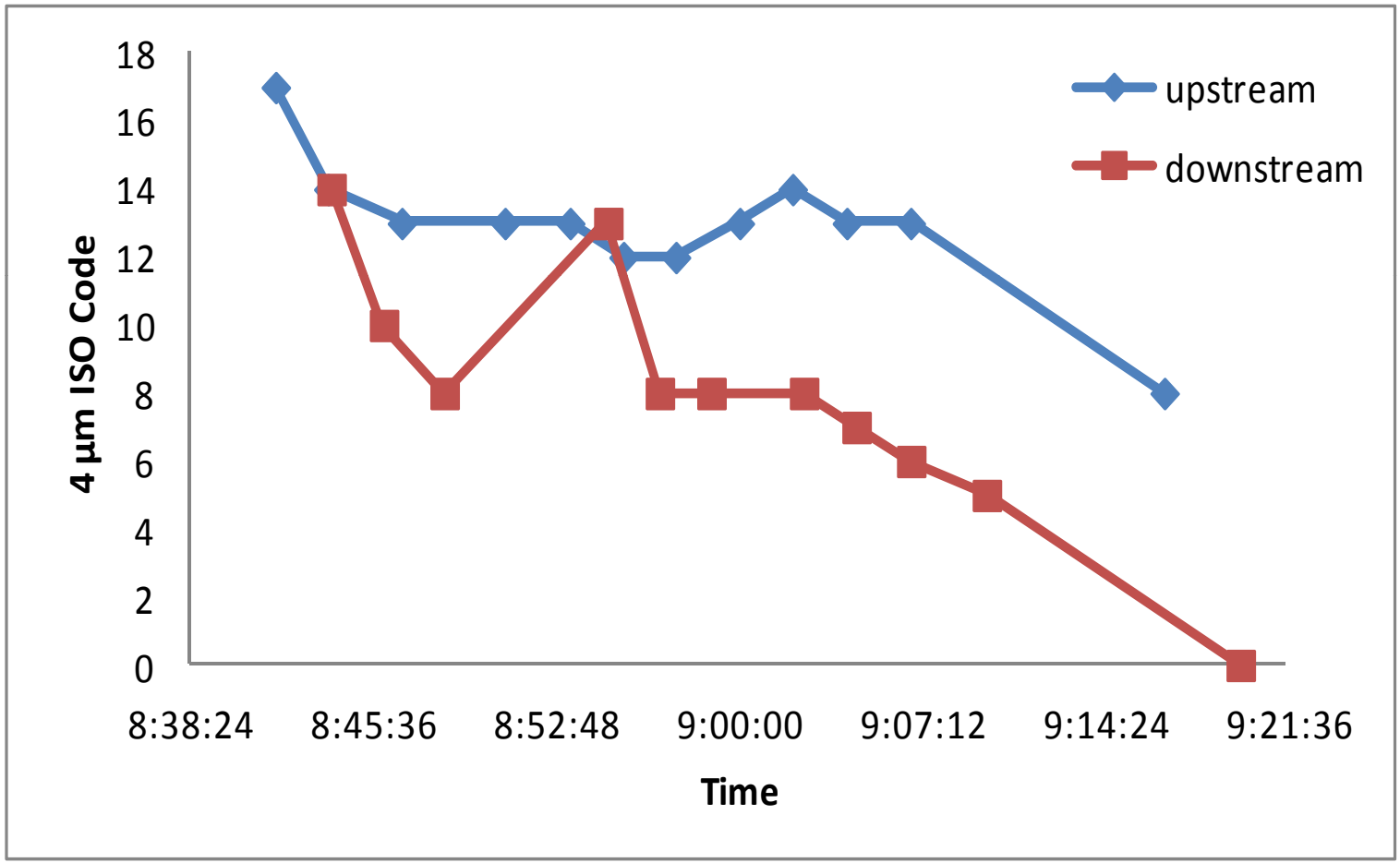
Unclassified

Site II – Location C - Testing

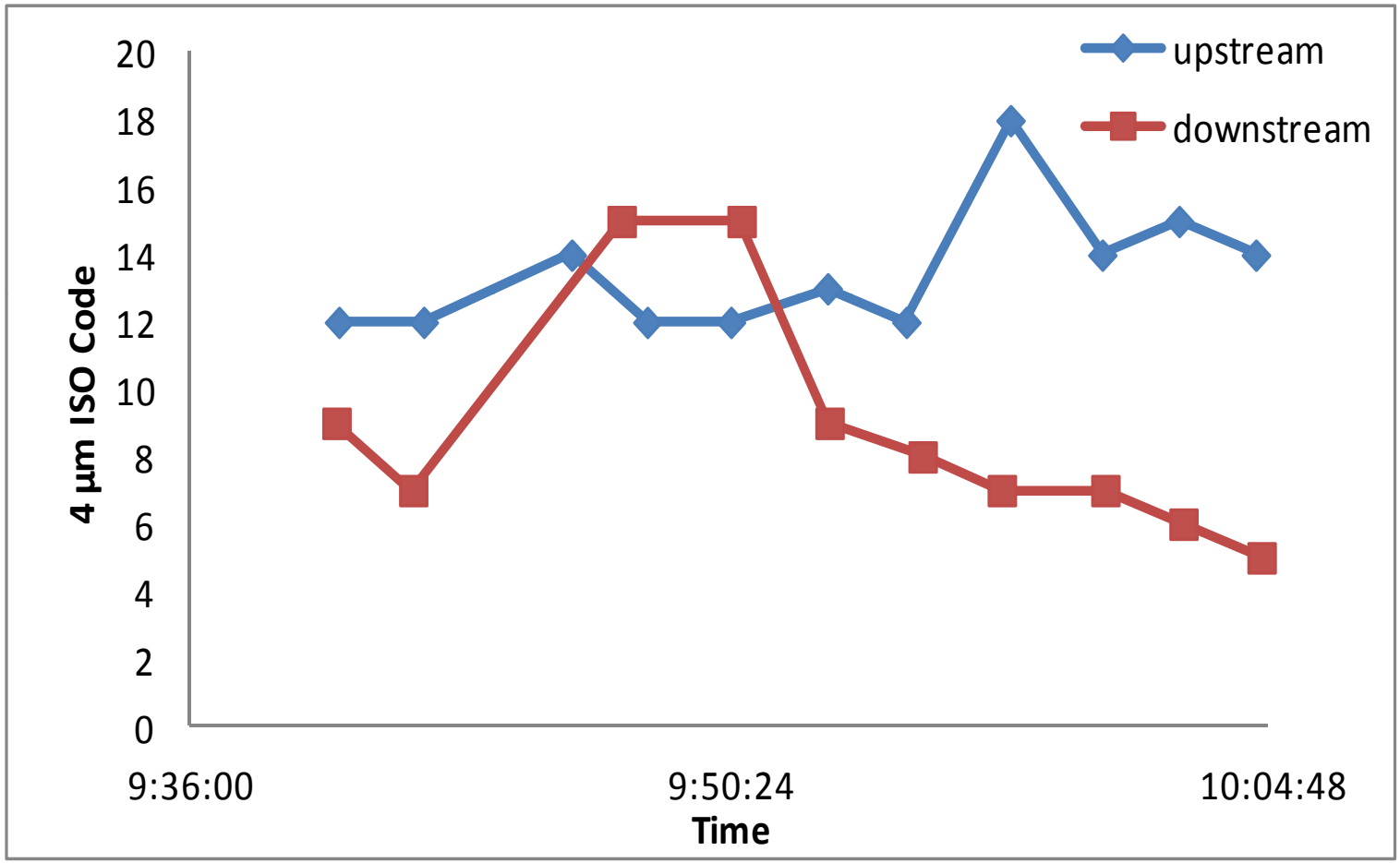
Site II – Location C - Testing

Online IOS testing

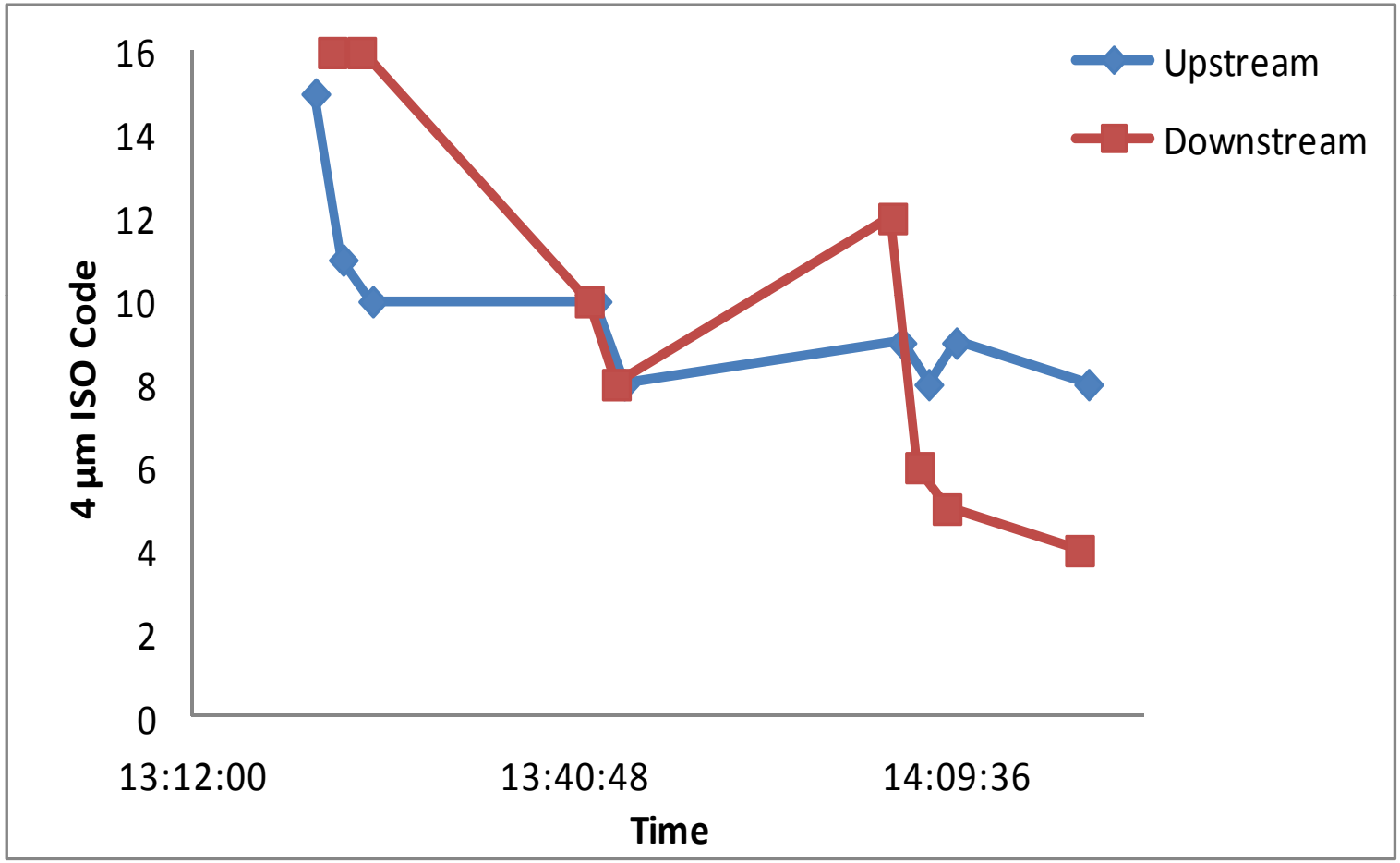
Site II – Location C – Samples 26 & 27



Site II – Location C – Samples 28 & 29



Site II – Location C
Issue samples 32 & 33



Site II – Location C
Issue samples

Time (EST)	*Location*	Sample #	Avcount	ACM20	S40 AVTUR	IcountOS
1300	upstream	5	17/15/11/7	17/14/10/6	17/15/11/-	15/13/9/7
1300	downstream	4	17/15/12/7	16/15/10/5	17/15/12/-	14/12/9/7
1340	upstream	3	17/15/12/9	17/15/11/7	17/15/12/-	16/14/12/10
1340	downstream	6	15/14/11/8	15/13/10/7	15/13/11/-	-
1355	upstream	11	17/15/12/8	16/14/10/6	16/14/11/-	13/11/7/6
1355	downstream	12	16/14/11/7	16/14/10/6	16/14/11/-	11/10/5/0
1435	upstream	9	17/15/12/9	16/14/11/7	16/15/12/-	-
1435	downstream	10	18/16/14/9	17/16/12/8	18/16/14/-	14/13/11/11
1300	upstream	17	17/15/10/6	17/14/9/5	17/15/11/-	12/11/8/4
1300	downstream	18	17/15/11/6	17/14/10/6	17/15/11/-	13/11/8/6
1320	upstream	32	17/15/11/7	17/15/10/7	17/15/11/-	15/13/10/7
1320	downstream	33	17/15/11/7	16/14/10/6	17/14/11/-	16/14/12/12

Conclusions

- Bottle sampling has the likelihood to induce contamination into measurements that is not present in the fuel stream.
- Particle counters are affected by air bubbles in the fuel stream.
- Proposed 19/17/14/13 is an acceptable working limit.
- 92F desire to replace existing aqua-glo free water testing.

Lessons Learned

- AFCTK sampling apparatus and bottles leak.

- AFCTK sampling hose has the potential to induce contamination.

- Sample port valves improve fuel sample cleanliness and reduce fuel spillage.