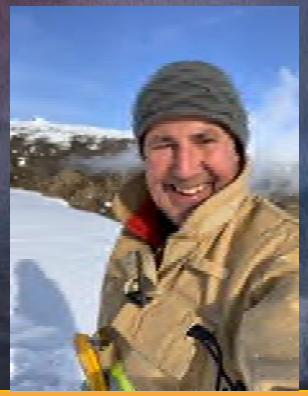
LATEST ADVANCES IN LANDFILL FIRE CONTROL
PART 1: The Five Step Method to Landfill Fire Suppression

Dr. Tony Sperling, P.Eng.
President
Landfill Fire Control, Inc.



- **PART 1:**
  - The Five Step Method to Landfill Fire Suppression
- **PART 2:**
  - Controlling the Burn: Landfill Fire Suppression Strategies
- **PART 3:**
  - Protecting Your Team: Landfill Fire Health and Safety
- **PART 4:**
  - Only You Can Prevent Landfill Fires: Risk Reduction and Prevention BMPs

Section 1. Introduction

- Course Agenda
- Learning about your backgrounds and goals
- Objectives
- Some Statistics
- Introduction to LFCI

Course Outline

1. Introductions
2. Panama Case History
3. Mechanics of Landfill Fires
4. Detecting Landfill Fires
5. Methods of Landfill Fire Control
6. Understanding Oxygen Suppression
7. Health and Safety
8. Landfill Fire Risk Reduction
9. Elevated Temperature Landfills
10. Whitehorse Case History

Compost Facility Fire Out of Control in Oregon.

Major Fire at Yellowknife Landfill

Getting to Know Each Other.

- Your name?
- Where are you from?
- Your responsibility?
- What are you hoping to get out of the course?

What's your experience?

- Have you experienced a fire at your facility?
- How frequently?
- What material ignited?
- How did you put it out?
- How long did it take?
- What was the main lesson you learned?

History of LFCI

- First retained to extinguish Penticton Fire in 1998 for existing engineering services client.
- In 2000 requested to assist Delta Fire Department in extinguishing huge fire at Delta Shake and Shingle.
- LFCI formed in 2000 to support landfill owners in dealing with landfill fires.
- Since then 54 landfill fire extinguishment projects completed by LFCI.

FIRE FIGHTING STRATEGY AND MANAGEMENT

Legend	
OV - Overhaul	14
OS - Oxygen Suppresion	30
WA - Water Application	12
WI - Water Injection	2
IG - Inert Gas	1
AB - Accelerated Burn	1
INV - Investigation	5
FA - Foam Application	4

	PROJECT DESCRIPTION	CONTACT NAME	Primary	Secondary	PHONE NUMBER	
1	Campbell Mountain Landfill	Dave Duckworth	OS		250-492-4121	Penticton, B.C.
2	Delta Shake and Shingle	Randall Wolsey	OV		708-496-3801	Delta, B.C.
3	Hespiria Landfill	Eric Jackson	OS		250-545-1361	Vernon, B.C.
4	Israel Carmon Landfill	Nimrod Halamish	INV			Ber Shiva, Israel
5	Vancouver DLC Fire	Paul Henderson	OS		604-946-8049	Delta, B.C.
6	Queen Charlotte Islands	Shelley Higman	OS		250-755-3421	McMillan Bloedel
7	Confidential Client	na	WI	OS	na	Burnsville, Minnesota
8	Atlantic Waste Systems	Peter Grootendorst	OS	WI	604-467-7397	Maple Ridge, B.C.
9	Gitwangak Sawmill 2003	Lisa Webster	OV		604-666-5299	Kitwanga, B.C.
10	Cathcart Landfill	Karl Hufnagel	OS		206-695-4509	Snohomish County, Wa.
11	Brother's Pit Fire	Jim Dias	AB		250-746-3112	District of North Cowichan
12	Metro Waste Gas Well Fire	Jeff Dworek	OS		515-967-2076 Ext 102	Des Moines, Iowa
13	Monroe County Landfill Fire 2004	Tobias Schroeder	OS		812-349-2865	Bloomington, Indiana
14	Bahamas Landfill Fire 2004	Judson Wilmott	WA		242-356-0218	Nassau, Bahamas
15	McKelvey Creek Fire 2004	Raymond Gaudart	OV		250-368-0232	Trail, B.C.
16	Highland Valley Mine Fire 2005	Bob Hamaguchi	WA		250-523-3237	Logan Lake, B.C.
17	Hazelbrook DLC Landfill Fire 2006	Garth Simons	WA		902-569-7746	Hazelbrook, P.E.I.
18	Pine Tree Landfill Fire, 2006	Jim Chabot	OS		603 229-1919	Casella, Maine
19	Confidential Client 2006	na	INV		na	Dalles, Oregon
20	Vancouver Landfill 2006 Fire	Lynn Belanger	OV		604-940-3201	Vancouver, B.C.
21	Dawson Creek Fire 2007 Fire	George Kunz	WA		250-784-2303	Dawson Creek, B.C.
22	Yellowknife Landfill 2007 Fire	Bruce Underhay	WA	FA		Yellowknife, NWT
23	Kona Hawaii Landfill Fire	Gary Siu	OS			Kona, Hawaii
24	Vancouver Landfill Fire 2009	Lynn Belanger	OS	WA	604-940-3201	Vancouver, B.C.
25	Ciudad Del Carmen Landfill Fire 2010	Ricardo Lopez Loredo	OS	WA	52-81-1366-4600 Ext 1139	Monterey, Nuevo Leon, Mexico
26	Brady Landfill Fire Investigation	Trevor Sims	OS		204-986-8043	Winnipeg, Manitoba
27	Calgary Metals Landfill Fire 2012	Chief Bruce Burrell	OV	FA	403-268 2489	Calagary, Alberta
28	Vernon Landfill Fire Investigation - 2013	Nicole Kohnert	OS		250-550-3741	Vernon, B.C.
29	Pasco Landfill Fire - 2014	William Goodhue, Jr.	OV	IG	206-780-7714	Pasco, Washington
30	Lakes County Landfill Fire - 2014	Mark Nelson	OS		406-883-7323	Polson, Montana
31	Cerro Patacon Landfill Fire - 2013	Enrique Ho	OS	FA		City of Panama, Panama
32	Iqaluit Landfill Fire - 2014	Luc Grandmaison	OV		1 867 979-5650	City of Iqaluit, Nunavut
33	Sk'way Landfill - 2015	Scott Postma	OS		604 775-0423	Tervita, Chilliwack, B.C.
34	Winnipeg Brady Landfill Fire - 2015	Irvin Slike	OS		1 204 986-4103	City of Winnipeg, Manitoba
35	Bovoni Landfill, St. Thomas - 2015	Steven Aubin	WA		1 340 715 9100	Virgin Islands Waste Authority
36	Aguilla Landfill, St. Croix - 2015	Steven Aubin	WA		1 340 715 9100	Virgin Islands Waste Authority
37	Harvest Power Spontaneous Combustion 2016		INV			Richmond, B.C.
38	Bailey Landfill Fire, 2017	Tara Friessen	OS		1 604 793-2701	City of Chilliwack
39	Calgary DLC Train ROW 2017	Marie Pierre Carrigan	OV		403 268-8269	City of Calgary
40	Watson Island DLC Fire Response	Bill Horne	OV			City of Prince Rupert
41	Vancouver Landfill Fire - 2018	Lynn Belanger	OS	OV	1 604 606-2730	City of Vancouver Transfer and Landfill Ops.
42	Whitehorse Landfill Fire - 2018	Geoff Quinsey	OS		1 867 668-8351	City of Whitehorse
43	Roatan Landfill Fire - 2018	Karen Ludlow	OS		9458 1486	Alcaldia Municipal, Roatan
44	Edson Landfill Fire, 2019	Bruce Thompson	OS		780-723-6461	Edson, Alberta
45	Glenmore Landfill Fire - 2020	Scott Hoekstra	INV		250-469-8588	City of Kelowna, B.C.
46	Larry's Scrap Yard Fire - 2021	Henry Dean	WA		1 242 557-2547	Nassau, Bahamas
47	Brown's Tree Care Fire - 2021	Robert Honea	OV		1 479 452-2200	Arkansas
48	Congress Landfill SSSER Data Review - 2022	Jeffery D. Jeep	ELTF		1 708 404-9090	Hillside, Illinois
49	Bristol Virginia SSSER Expert Reviewer - 2022	Mark Widdowson	ELTF		1 540 231-9836	Blacksburg, Virginia
50	Raglan Mine Landfill Fire Extinguishment - 2022	Benoit Desroches	OV		+1 819 762 7800 x 4563	Nunavik, Northern Quebec
51	Oregon Wood Waste Fire - 2022	Erik Bakkom	INV		1 503 501-5217	Bend, Oregon
52	Caton Landfill Fire Oxygen Suppression - 2022	Randall Caton	OS		1 509 728-8928	Naches, Washington
53	DTG Landfill Fire Oxygen Suppression - 2023	Ian Sutton	OS		1 425 549-3000	Yakima, Washington
54	Kelowna - 2023	Candice Pilling	WA	FA	250-469-8588	Kelowna, B.C.
55	Barro Sunshine Landfill - 2023	Nino Frascasa	OS		250-469-8588	Melbourne, Victoria, Australia
56	Kona Hawaii Landfill Fire - 2023	Myounghee Noh	OS		808.484.9214	Kona, Hawaii
57	Oregon University Landfill Fire - 2024	Gosh Gobershock	OV			Bend, Oregon
58	Prince Rupert Landfill Fire -2025	Jordan Schmidt	OS	WA		Prince Rupert, B.C.
59	Providence Landfill - 2025	Estelle Lau Ti	OS			Victoria, Mahe, Seychelles

LFCI EXPERIENCE 59 Successful Landfill Fire Extinguishments

The Five Step Method to Landfill Fire Suppression

Dr. Tony Sperling, P.Eng.

Delta Shake and Shingle Fire, 1999

Fire At Brother's DLC Facility - 2001

Incident Command Vancouver Fire, 2009

Dr. Tony Sperling, P.Eng.

Site Command, Cerro Patacon Panama, 2013

Incident Command Vancouver Fire - 2018

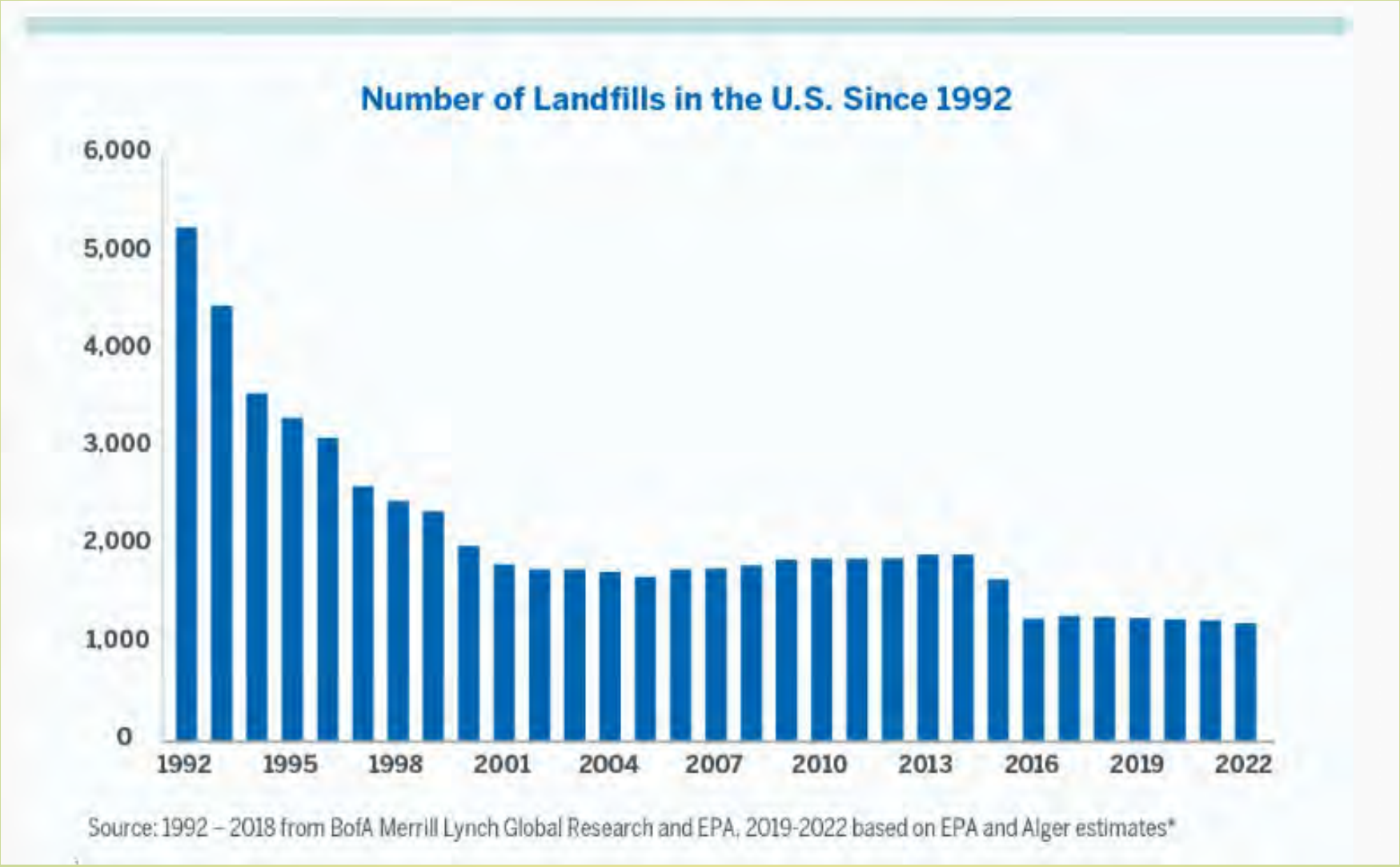
Services Provided by LFCI

- Fire Suppression (59 projects)
- Fire Prevention Audits (14 projects)
- Fire Response Training (42 projects)
- Consultations (numerous)

- Providing Annual Landfill Fire E-Course for Solid Waste Association of North America, over 300 people participated

Landfill Staff and Fire Dept. Training Comox Strathcona R.D.

Number of Landfills in U.S.



The Statistics

- About 1,500 landfills in U.S.
- Over 8,300 dump or sanitary landfill fires reported in U.S. annually according to National Fire Incident Records.
- Average of 9 fires per year at most landfills.
- Most fires are small and easily managed.
- One in 200 fires escalates to a major incident.
- Probability of major fire estimated at 0.5%.
- Delta Shake Fire in 1999 cost $4 million.
- Brother's Recycling Fire in 2002 cost $400,000.
- Vancouver Landfill Fire in 2009 Cost $1.2 million.
- Vancouver Landfill Fire in 2018 Cost $2.0 million
- Bridgeton ETLF cost over $500 million

COURSE OBJECTIVES

- To learn how to:
  - Recognize warning signs.
  - Learn the 5 Step Response System
  - Plan case specific response strategies.
  - Quickly implement Incident Command.
  - Ensure safety of all staff fighting fire.
  - Minimize risk of fire occurring.
  - Develop an effective Pre-Plan for your facilities.
  - Coordinate response by landfill staff and Fire Department.

LFCI Staff

- Dr. Tony Sperling, P.Eng. (Landfill Engineer)
- Todd Thalhamer, P.E. (Env. Emergency Responder)
- Dr. Ali Abedini, P.Eng. (Landfill Gas Specialist)
- Dr. Bently Higgs (Landfill Operations Specialist)

- Engineering support from SHA.
- Fire fighting support from local Fire Departments and Contractors

Dr. Tony Sperling, P.Eng.

President
Landfill Fire Control, Inc.

- Landfill design engineer with 34 years experience
- Experience fighting more than 50 major landfill fires
- Active in landfill fire research
- SWANA MOLO Instructor

Todd Thalhamer, P.E.

- Environmental Engineer with 20 years experience in waste issues
- 18 years of firefighting experience
- Currently a volunteer Lieutenant for El Dorado Hills Fire, California
- Developed a new firefighting concept called environmental suppression, which balances the impact of firefighting with the environment
- Consulted on over 40 waste fire projects in the US and Internationally
- IC for the Longest Burning Tire Fire in the US
- President of Hammer Consulting

Unified Command Structure – Delta Fire

Emergency Ops. Center Commander
Randall Wolsey

Media Liason
Patti Schom-Moffatt

WHAT TO DO	GET	DO	PAY	OVERSEE
Engineering and Planning Sperling Hansen Dr. Tony Sperling	Logistics Delta Fred Growski	Operations Incident Commanders Ed Black Gordon Freeborn Steve Svensson	Finance Delta Finance Dept. Don Claybo	Regulators & Stakeholders

- Engineering Support
  Sperling Hansen
- Fire Figting Strategy
  Safety Boss Canada
  Jarvis Jackson
- Geotechnical
  Horizon Engineering
  Saman Vazinkhoo
  Karen Savage
  - MacElhanney Surveyors
  - Drilling Contractors
- B.C. Gas Utility

- Safety Officer
- JJM Construction
  Martin Middleton
  Heavy Equipment
  Labourers
- Delta Fire Dept.
  6 Fire Fighters
  Monitors & Hoses
  Pumper Truck
- Delta Public Works
  Leachate Control
  Pump Rentals
  Pump Operators

- B.C. Environment
  Ed Lai
  Jeff Van Haastregt
- GVRD
  Air Quality Ken Stubbs
  Source Control Meegan Armstrong
  Solid Waste Rick Laird
- WCB
  Ian Salomon
- South Fraser Health Region
  Bill Rogers
  Dr. R. Guasparini
- PEP
  Ryna Brideau
- Delta Environmental Services
  Bernita iverson
  Verne Kucy

Acknowledgements

- Thanks to Stuart Dever, University of New South Wales as the point person for making this course a reality and the concerence volunteers for organizing the event and staying in touch with all of you, setting up venue. Couldn't have done it without them!!

LFCI 5 Step Systematic Approach

1. Health and Safety Plan
2. Establish Control
3. Contain Fire
4. Extinguish Fire
5. Monitor to Confirm Extinguishment

Step 1. Health and Safety

- How bad is the smoke?
  - Ensure appropriate respiratory protection
  - Full face respirator or SCBA
- PPE
  - Turn out gear or Nomex overalls
  - Proper boots
  - Gloves, Helmet, Eye Protection
- Air Quality Monitoring
  - CO, H2S, O2
- Daily safety briefing

Respiratory Protection & Appropriate PPE

Step 2. Establish Control

In this task all active areas of combustion are rapidly covered by soil, waste or Posi-Shell. All visible flame is eliminated. Suppressing easy access to oxygen cuts smoke emissions dramatically, usually by more than 90%. A much safer work site is created.

Dozers in Thick Smoke

Control Oxygen to reduce smoke and fire intensity

Step 3. Achieve Containment

A fire suppression method (or combination of methods) is selected to fight the fire. Fire breaks are established to prevent spread of fire. Fire suppression activities are undertaken to contain the fire. All visible smoke is eliminated.

Containment in Vancouver – Chasing 3 big worm holes

Step 4. Extinguish Fire

Mop up activities continue, pursuing all active fire areas where temperature and/or carbon monoxide monitoring indicates that combustion is still occurring. Extinguishment is declared when all subsurface CO readings drop below 500 ppm.

Mopping up in Panama

Step 5. Confirm Extinguishment by Monitoring

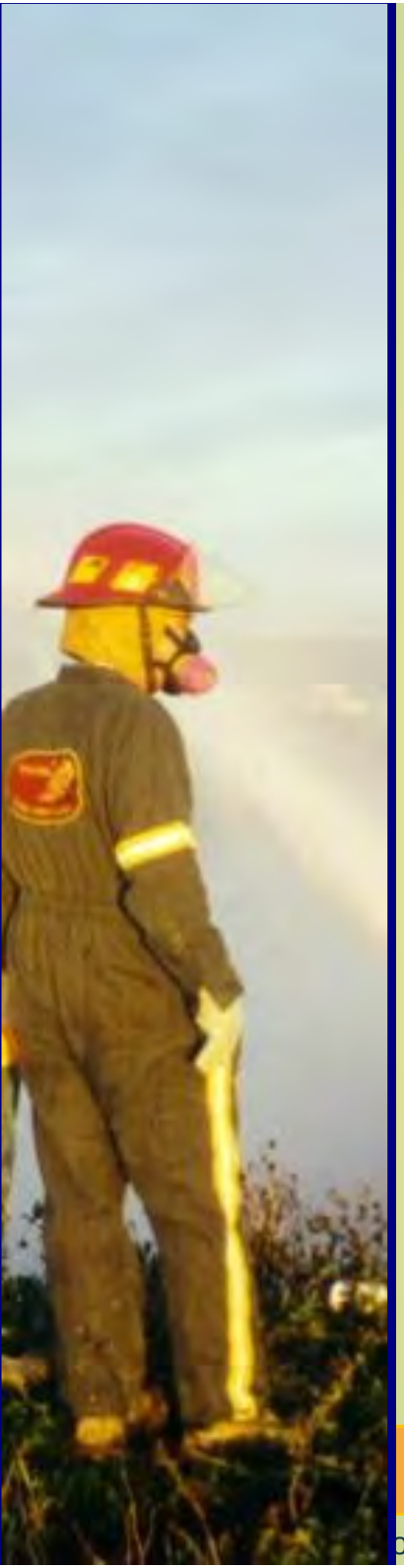
Time and again, we have found that subsurface carbon monoxide concentrations provide an accurate indicator for ongoing combustion in landfills. As long as CO levels exceed 1,000 ppm, there is a high degree of certainty that a fire continues to burn, or a chemical reaction continues to occur within the landfill. By conducting post suppression monitoring, you will be able to conclusively demonstrate that the fires have been extinguished.

Section 1 Review:

- How many landfills exist in North America today?
  a) 1,500
  b) 10,000
  c) 5,000
- How many fires typically occur at landfills on average in any given year?
  a) 9
  b) 4
  c) 2
  d) Very Rare

Section 1 Review Continued:

- In the five step method of fire suppression, what is the second step?
  a) Contain
  b) Health and Safety
  c) Establish Control
  d) Extinguishment
- What is the goal of Establishing Control?
  a) Eliminate all smoke
  b) Reduce smoke by 90% and no open flame
  c) Control CO to below 1,000 ppm
  d) Cut off all oxygen



Section 2. Panama Case History

- Background
- Initial Response
- Establishing Control
- Implementing Unified Command
- Containing the Fire
- Achieving Complete Extinguishment

City of Panama is capital of Panama with population of 1.3 million in Metro Area

Mira Flores Lock, Panama

Evening of March 20th

March 20th Evening Newscast

Morning of March 21st

Evening of March 21st

Fire History

- Fire initiated Evening of on March 20th
- By morning entire upper portion of landfill on fire
- About 6 Ha (15 acres of area on fire)
- Fire continued to grow for 2 days
  - LFCI consulted on strategy on March 22nd.
  - Options to extinguish include blowing landfill up
  - Decision made to control fire with dirt
- LFCI team arrives on ground March 26th
- Fire under control by April 4th (2 weeks)
- Fire Extinguished April 24th (5 weeks)

Smoke envelops City of Pamama March 21st

Team mobilized on Mach 21st in presidential jet

Media interest was huge.

Establishing control with Class A foam

Fire truck monitors used to spray foam

Landfill surface covered with 300 mm of dirt

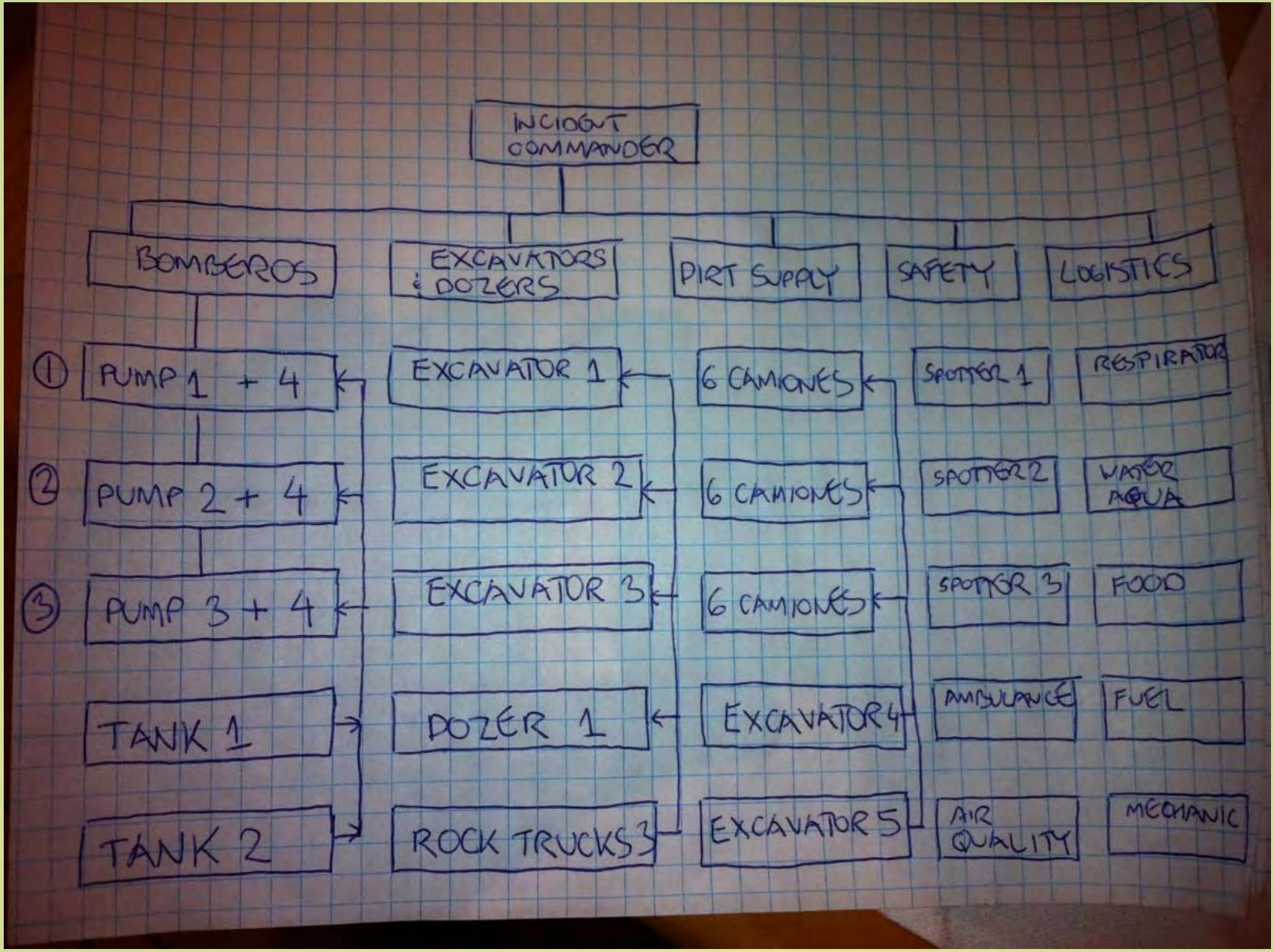
Hot spots continued to burn sub-surface

Most slopes were really steep, up to 1.5H:1V

This truck got too close to flames

Catastrophic roll – over, driver escaped!!

Tipping Procedures were not safe


INCIDENT COMMANDER
BOMBEROS
EXCAVATORS & DOZERS
DIRT SUPPLY
SAFETY
LOGISTICS
1
PUMP 1 + 4
EXCAVATOR 1
6 CAMIONES
SPOTTER 1
RESPIRATOR
2
PUMP 2 + 4
EXCAVATOR 2
6 CAMIONES
SPOTTER 2
WATER AQUA
3
PUMP 3 + 4
EXCAVATOR 3
6 CAMIONES
SPOTTER 3
FOOD
TANK 1
DOZER 1
EXCAVATOR 4
AMBULANCE
FUEL
TANK 2
ROCK TRUCKS 3
EXCAVATOR 5
AIR QUALITY
MECHANIC

	EQPT	HOMBRES
EXCAVATORS	5	5
ROCK TRUCKS	3	3
CAMIONES	18	18
DOZER	1	1
BACK HOE	1	1
PUMP	3	12
TANKER	2	4
AMBULANCE	1	2
	34	46
SPOTTERS	6	3
AIR QUALITY	1	1
LOGISTICS	2	4
MECHANICS	1	2
SECURITY	2	4
INCIDENT COMMAND	1	2
BOMBERO COMMAND	1	2
EXCAVATOR COMMAND	1	2
DRT COMMAND	1	2
	10	22

Health and Safety Meeting

Getting ready to attack 56 hot spots

Step 1. Todd Thalhammer using hand line

Stockpilling dirt was step 2.

Each team included pumper with 4 Bomberos, excavator, tanker, dozer

Establishing access ramp to hot spot

Step 3. Opening up a hot spot.

Waste usually flared up once exposed to air

Slope stability and safety of ground crews was my biggest concern

Bomberos working in concert with excavator

Step 4. Thoroughly foaming excavated material.

Always working in pairs

Heat was brutal, day time temps of 42C

Maintaining Hydration and electrolytes critical

El Coral. Red on yellow kills a fellow.

Command team celebrating fire under control.
April 4th, 2013

Honourary Bombero. Making my day!!

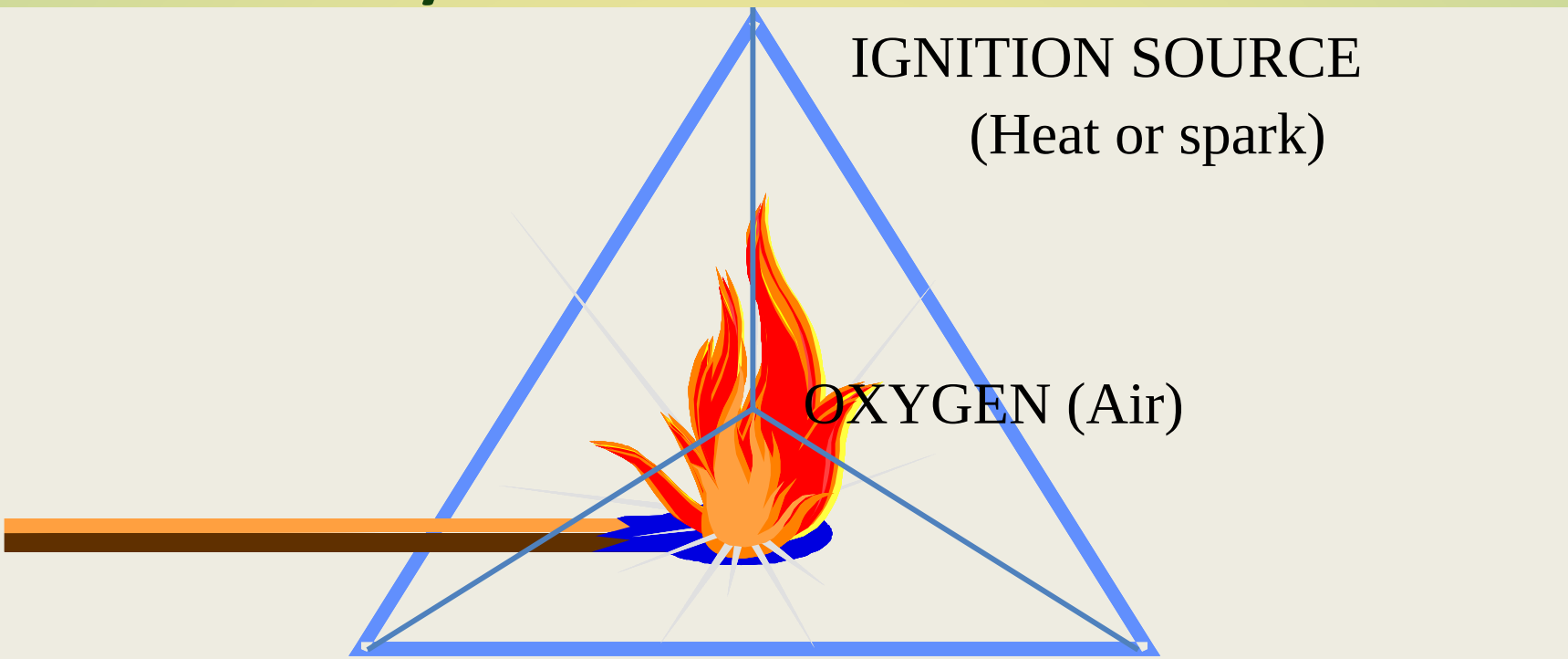
Final celebration and awards, late April.

END OF SECTION 2

Section 3. Mechanics of Landfill Fire

- Energy Content
- Ignition Methods
- Landfill Fire Alert Levels

The Fire Pyramid or “Tetrahedron”.



Roatan Little Smoker

LANDFILLFIRE.com

FUEL AVAILABILITY

- Solid waste is a high energy fuel:
  - MSW is 4,000 to 7,000 BTU/lb
  - Demolition/Land-Clearing/Construction (C&D) waste is 6,500 BTU/lb
  - Gasoline is 15,000 BTU/lb
- Regional landfills are huge stockpiles of flammable material.
- For example, Vancouver Landfill:
  - 35 years of operation
  - 12 million tons in place
  - equivalent to 1.5 billion gallons of gasoline
  - enough energy to power Vancouver for 6 years.

Typical MSW - Cache Creek Landfill

Typical C&D, Metro Landfill, Des Moines

EcoWaste Demolition Waste Landfill

The Five Step Method to Landfill Fire Suppression

Dr. Tony Sperling, P.Eng.

Construction / Demolition Waste – New York

Walking Floor Trailer full of Auto-Fluff
Brookhaven, New York

Auto-Fluff on fire at Calgary Fire Academy.

C&D Fire At Brother's DLC Facility

Method to Landfill Fire Suppression

Dr. Tony Sperling, P.Eng.

Landfill Fire Statistics

- Types and frequency of fires occurring at landfills according to National Fire Incident Reporting System:
  - Refuse fires 77%
  - Trees, Brush 12%
  - Outside Structures 7%
  - Vehicles 1%

IGNITION SOURCES

- Embers in a hot load;
- Careless smoking;
- Reactive substances;
- Methane flash from equipment spark;
- Lightning Strike;
- Arson; and
- Spontaneous Combustion
- Marine Flares
- Batteries!!

Hot load started fire at Keremeos.

Reactive Sawdust Load, Calgary.

Magnesium Chloride (aluminum dross)

Waste Connection, Ore.

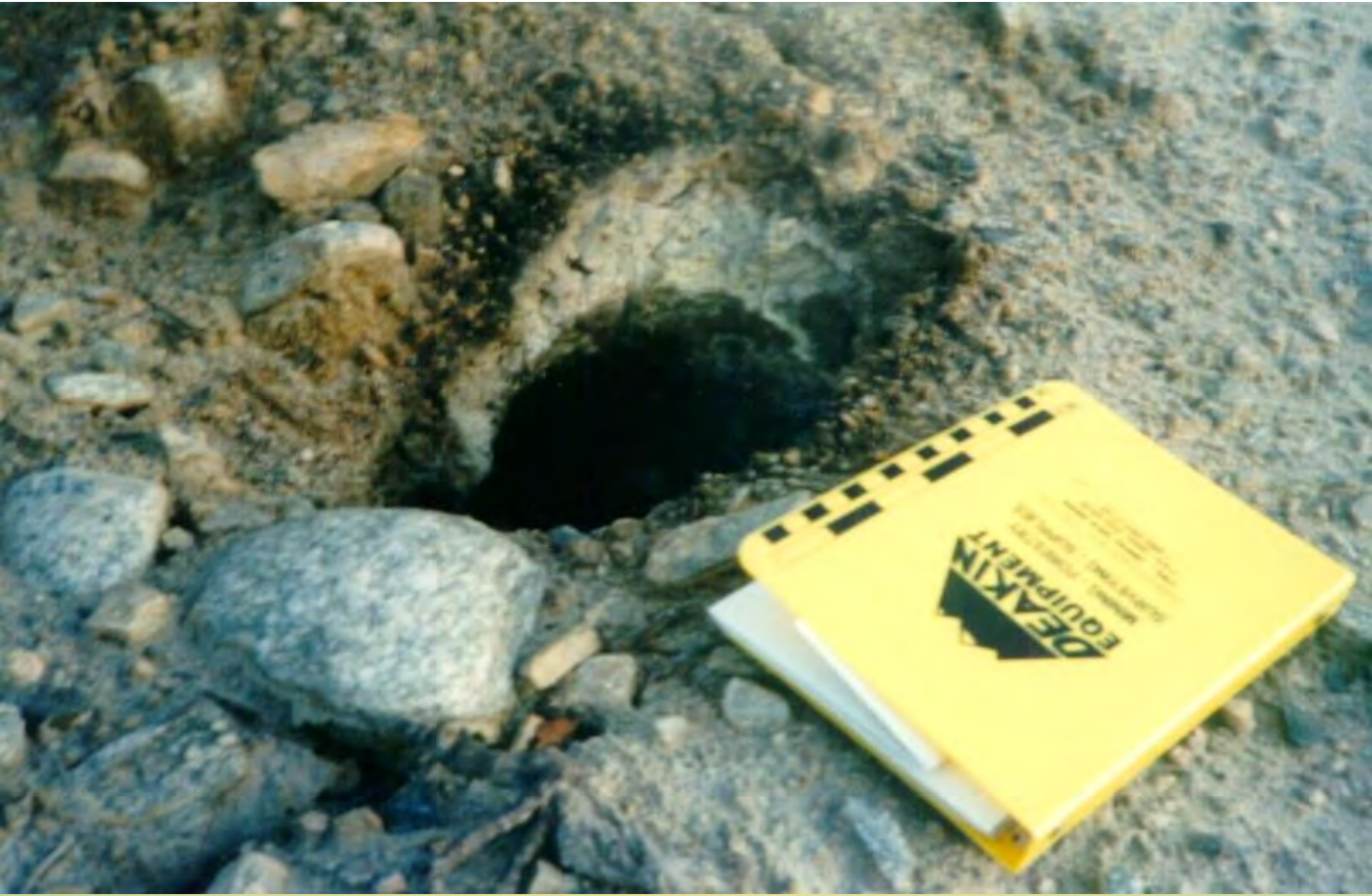
Reactive Loads Batteries, Ammunition and Flares

SPONTANEOUS COMBUSTION

- Spontaneous combustion is the outbreak of fire without application of heat from an external source.

Spontaneous Combustion Process:

- Anaerobic Decomposition
- Aerobic Decomposition
- Pyrolysis
- Exothermic Oxidation of Wood
- Wood Ignites Spontaneously (Combustion)



Spontaneous Combustion Fumarole

Oxygen Intrusion at Hiria Landfill, Tel-Aviv Israel.

Steep poorly covered slopes at Hiria.

Spontaneous Ignition at Hiria Landfill, Israel.

Collapse feature, Carmon Landfill – Israel.

Spontaneous Combustion at Delta Shake

Method to Landfill Fire Suppression

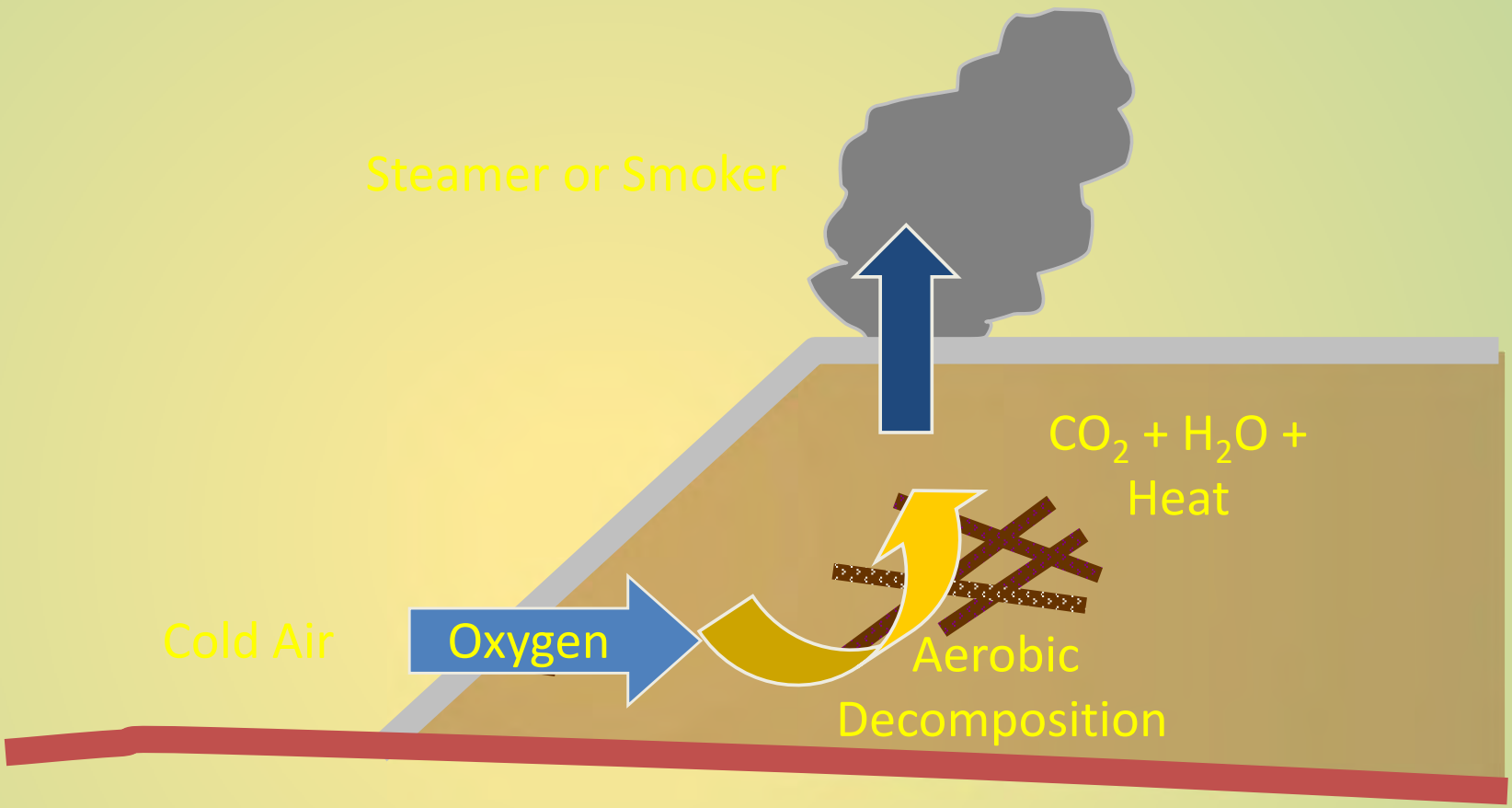
Dr. Tony Sperling, P.Eng.

40,000 m3 spontaneous combustion fire, Brothers Recycling, Duncan B.C.

Roatan Island Dump Site, Honduras

200,000 m3 of organic MSW

LANDFILLFIRE.com



Convection Mechanics on Slope

Landfill Fire Magnitude

- **Level 1 - Non-Refuse Fires: Fires on landfill property not involving landfilled refuse, compost or stockpiled recyclables.**
- **Level 2 - Small Fires: Small refuse fires that can be contained within 24 hours, less than 500 m^3 of burning material.**
- **Level 3 - Medium Fires: Medium size fires that can be contained in less than one week, typically 200 to 5,000 m^3 of waste material are involved.**
- **Level 4 - Large Fires: Large or Deep Seated Landfill Fires that require more than two weeks to contain, typically involving more than 5,000 m^3 of burning refuse.**
- **Level 5 – ETLF or SSER: More than 50,000 m^3 of refuse, months to years to extinguish.**

Level 1 - Non Refuse Fire. Car Fire

Level 1 - Non-Refuse Fire. Garbage Truck on Fire

Level 2 - Small Fire in Landfill.

Intentional Ignition at Laxgalts'ap Landfill

Level 2 - Small Fire at Keremeos Landfill Active Face.

Level 3 - Medium Fire at Compost Facility.

Fires up to 5,000 m3, less than 1 week.

Level 3 - Medium Fire in Dawson Creek, B.C.

Level 3 – Medium Fire in Whitehorse, Yukon Territory

Level 4 - Large Fire – Delta Shake and Shingle C&D Site. Over 200,000 m3

Level 4 Large Fire – Vancouver Landfill

Level 4 - Calgary Metals Auto Fluff Fire

Level 5 - ETLF – Bridgeton Landfill. St. Louis, Missouri.

Section 3 Review:

- Spontaneous combustion is the initiation of fire without an external source? (T or F)
- Continuous oxygen supply is needed to sustain combustion? (T or F)
- Municipal solid waste has an energy content about 1/10 that of gasoline. (T or F)
- Level 4 fires can be extinguished in less than one week. (T or F)
- Fine sawdust, magnesium chloride and flares are all:

a) Dangerous goods
b) Potentially reactive
c) special wastes
d) hard to handle

END OF SECTION 3

Section 4. Detecting Landfill Fires

- Visual Signs of Fire.
- Settlement.
- Gas Monitoring.
- Temperature Monitoring.


If you can stay calm, while all around you is chaos … then you probably haven't completely understood the seriousness of the situation.

SIGNS OF LANDFILL FIRE

- Fire breaking out at surface.
- Collapse feature at surface.
- Venting gases.
  - Coloured smoke.
  - Distinct odour.
  - Carbon monoxide > 500 ppm.
- Temperature at surface > 60^{o} C (140F).

Fire Breaking Out at Yellowknife

Dr. Tony Sperling, P.Eng.

Small fire at active face.

Flame in old burn pit. Terrace, B.C.

Smoke Plume at Brother's Recycling

Smoke in DLC Landfill, Maple Ridge.

Horseshoe Inspection Three Weeks before Fire Reported on November 8th, 2000 at Delta.

Typical vent, Terrace, B.C.

Note smoke coming from vent.

Smoking vent, Penticton, B.C.

Venting without smoke

Warning!!!

- Don’t sniff smoke or gas coming from vents, fumaroles, steamers, smokers or wells.
- Gases can be deadly toxic – CO, H_2S, methane, dioxins, organics, etc.

Surface Settlement

- Landfill fire creates air space!!!
- As gases and ash produced, void space is created.
- Large cavities can form, bridged by cover soil.
- When cover fails, sink hole is formed.
- Use caution when working in fire areas.
- Probe ahead when first deploying heavy equipment.
- WARNING: Workers have been badly burned falling into sink holes.
- Always use buddy system.

Settlement Due to a LF Fire

Collapse Feature - Gitwangak

Major Settlement Crack, Terrace.

Major Sinkhole, Carmon Landfill Israel.

Sink Holes

- 16 year old – three degree burns 30%
- Fell into 15’ deep hole

  X-mas eve

- Equipment damage $$$

Youth slips into burning Bend sinkhole

☐ Lyle Zimmerman, 16, is badly burned in an accident at a buried county landfill

From staff and wire reports

BEND — Workers have posted signs and fenced off the park district land where a 16-year-old boy fell into a burning sinkhole — the remnant of a buried county landfill.

Lyle Wayne Zimmerman, 16, suffered third-degree burns on his hands and other burns across 30 percent of his body in the Christmas Eve accident.

"Lyle doesn't remember much, but he told me he thought he had fallen into a 15-foot-deep hell hole," his mother, Mona Laager, said after the accident.

Zimmerman remained in serious condition Friday in the burn unit at Emanuel Hospital & Health Center in Portland.

Family members and friends questioned why the sinkhole had not previously been fenced off or marked with warning signs.

"Why the hell didn't they post the place?" asked Gene Draper, the father of another boy, Larry Draper, who was with Zimmerman when he fell.

"Anybody could have fallen into that hole," the elder Draper said. "It's a death trap up there."

Park district director Ernie Drapela said Friday his agency was very disturbed by the accident.

The district had planned to put children's baseball diamonds on an unused portion of the old landfill site, he said, but shelved the plan a year ago after conferring with the Department of Environmental Quality.

"This goes well beyond anything we had anticipated would happen," he said.

The park district was unaware of hot spots or sinkholes, he said.

Larry Draper said he and Zimmerman had noticed a thin trail of smoke coming from the ground while they were walking home Christmas Eve and went to investigate.

"There was a little hole there, and we were looking into it. Then the ground that Lyle was standing on fell in," Draper said.

"He yelled that he was on fire. ... There was just a lot of smoke. He reached his hand up, but I couldn't pull him up."

Passers-by helped him pull Zimmerman from the hole.

"It was really bad," Draper said. "His hands looked like there was gloves on them but there wasn't."

The Department of Environmental Quality will inspect the land next week.

The sinkhole is on a 13.75-acre parcel of park district land leased by Mount Bachelor Inc. on the outskirts of Bend.

The resort has its offices and shuttle van parking lot on the site. The remainder of the landfill area, about six acres, is unused.

Workers fenced off a half-acre, including the 5-foot-deep sinkhole, and more dirt was laid over the site.

The landfill was owned by the county and given to the park district. The dump was used for wood waste, such as shavings or lumber or chemicals used in wood processing, Drapela said.

The decomposing debris smoldered and ignited through spontaneous combustion, he said. Burned-out pockets cause the ground cover to weaken and collapse.

Most of the problem areas are along the edges of the landfill, where the earthen cap used to cover the waste is thinnest, he said.

"It just makes me sick because I've got four kids," Drapela said.

Laager, a single mother of two, said her son would require skin grafts and probably would be hospitalized at least a month.

She said her family was dependent on food stamps and had no health insurance.

"It's going to be a hard time, but he's alive — that's what we're thankful for," she said.

Drapela said the park district had met with its insurer and was determining the extent of its responsibility for the accident.

"The county and the district and Mount Bachelor are going to have to confer with insurance and legal people to clarify all these questions," Drapela said.

Temperature Ranges - Metric

- <60°C Anaerobic Decomposition
- <75°C Aerobic Decomposition
- 80°C Bugs Die Off
- 93°C Pyrolysis Starts (chemical oxidation of wood)
- 149°C Exothermic Chemical Decay Starts
- 316°C Wood Ignites Spontaneously (Combustion)

Temperatures Leading to Fire

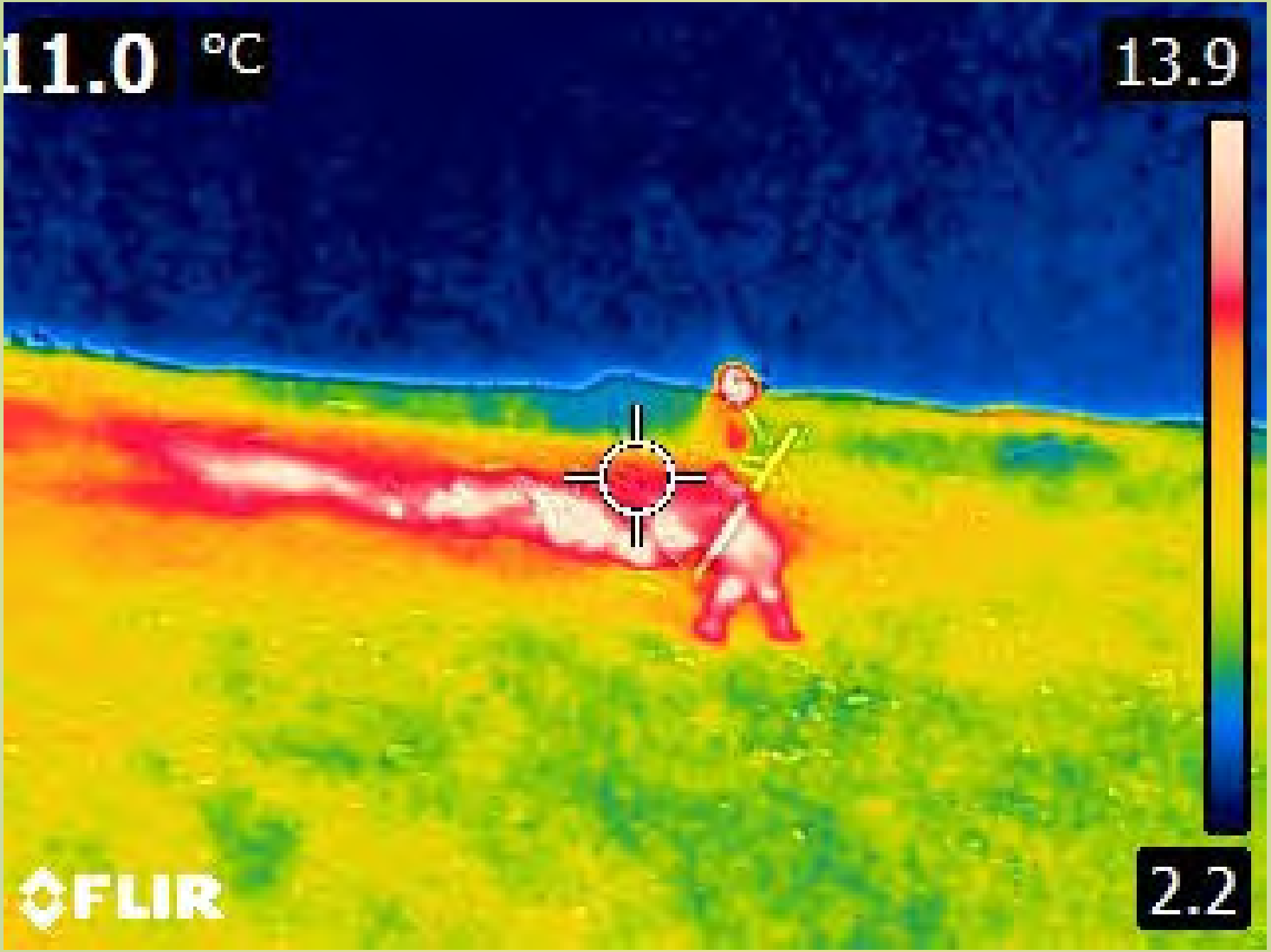
- <140°F Anaerobic Decomposition
- <167°F Aerobic Decomposition
- 176°F Microbes Die-off
- 200°F Pyrolysis Starts
- 300°F Exothermic Oxidation of Wood Starts
- 600°F Wood Ignites Spontaneously (Combustion)

Table 2. LFCI Temperature Scale Identifying Key Temperature Ranges

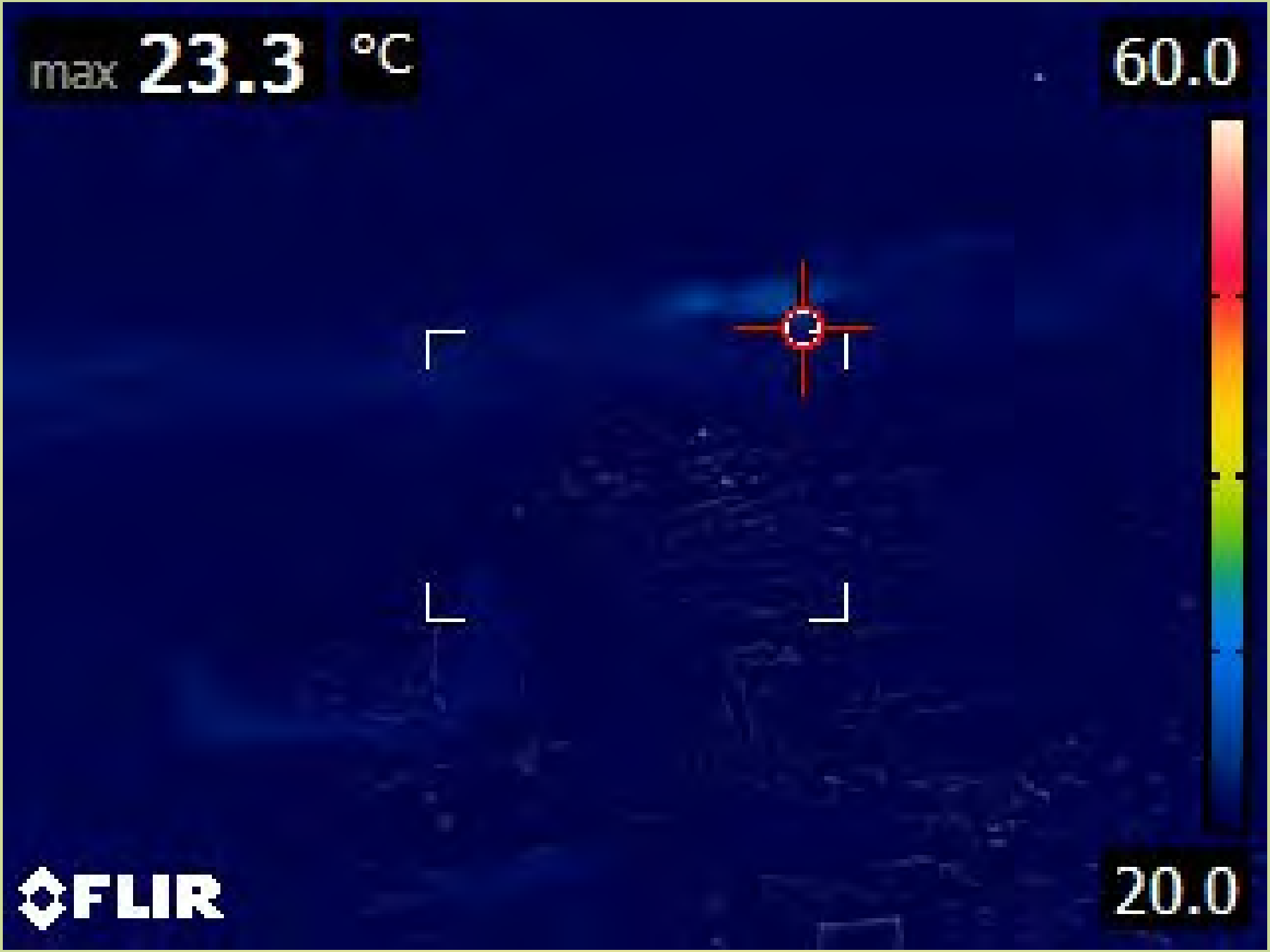
Fahrenteit Deg F	Celcius Deg C			
1,832	1,000	Fire		Fire
1,382	750			
932	500			
608	320		Upper Limit of Torrefaction (low temp. Pyrolysis)	
601	316		Wood ignites spontaneously	
500	260	Exothermic Deay of Wood		Exothermic Pyrolysis
400	204			
392	200			
392	200		Minimum temperature for Industrial Water Gas Shift Reaction (fast)	
324	162		Melting point of EVOH Resin	
300	149			
290	143	Suspected Subsurface Exothermic Reaction in MSW		Possible Exothermic Reactions
280	138			
270	132		Melting point of HDPE Liner (125 to 130C)	
260	127			
250	121			
240	116			
230	110			
220	104		Trigger Temperature for Exothermic Chemical Activity (104C)	
212	100		Boiling Point of Water	
210	99	Heat Transfer and Exothermic Metal Oxidation		Chemical Heating Up
200	93			
190	88			
180	82			
176	80		Maximum Biological Temperature per LFCI experience	
175	79		Trigger for Elevated Temperatures in Gas Extraction Wells	
170	77			
167	75	Aerobic Biological Decomposition	Upper Limit of Aerobic Biologic Decomposition Temps.	Aerobic Warm
165	74		Maximum temperature for methanogenesis	
160	71			
150	66			
145	63		Temperature to which vaiance issued for running hot wells	
140	60			
131	55	Anaerobic Biological Decomposition	NSPS standard for maximum temperature in well	Anaerobic Normal
130	54			
120	49			
110	43			
100	38			
90	32			
80	27			
70	21			
60	16			

Temperature scanning for hot loads.

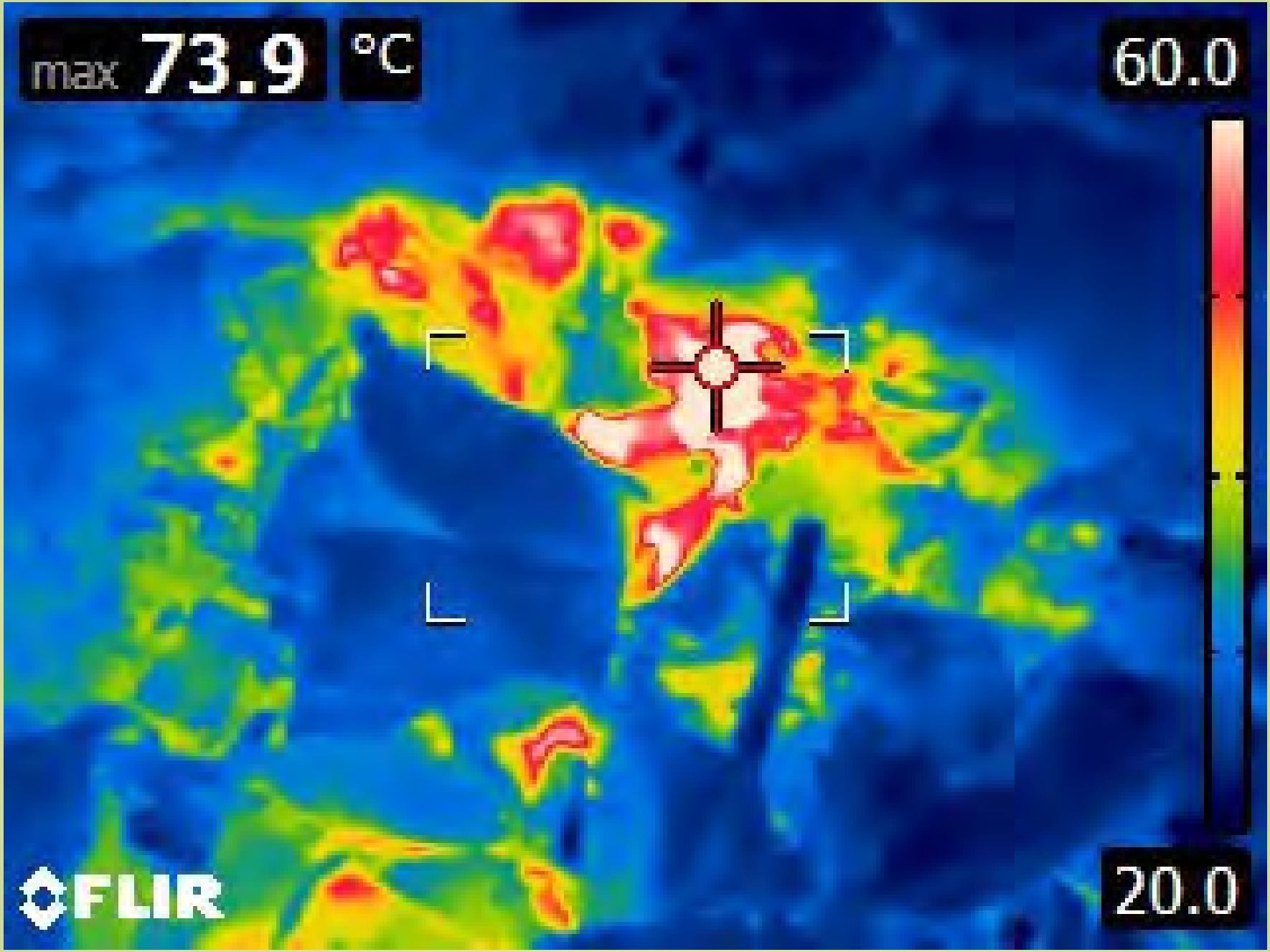
Infrared Cameras revolutionized Temp Analysis



Infrared Image – Flir Camera



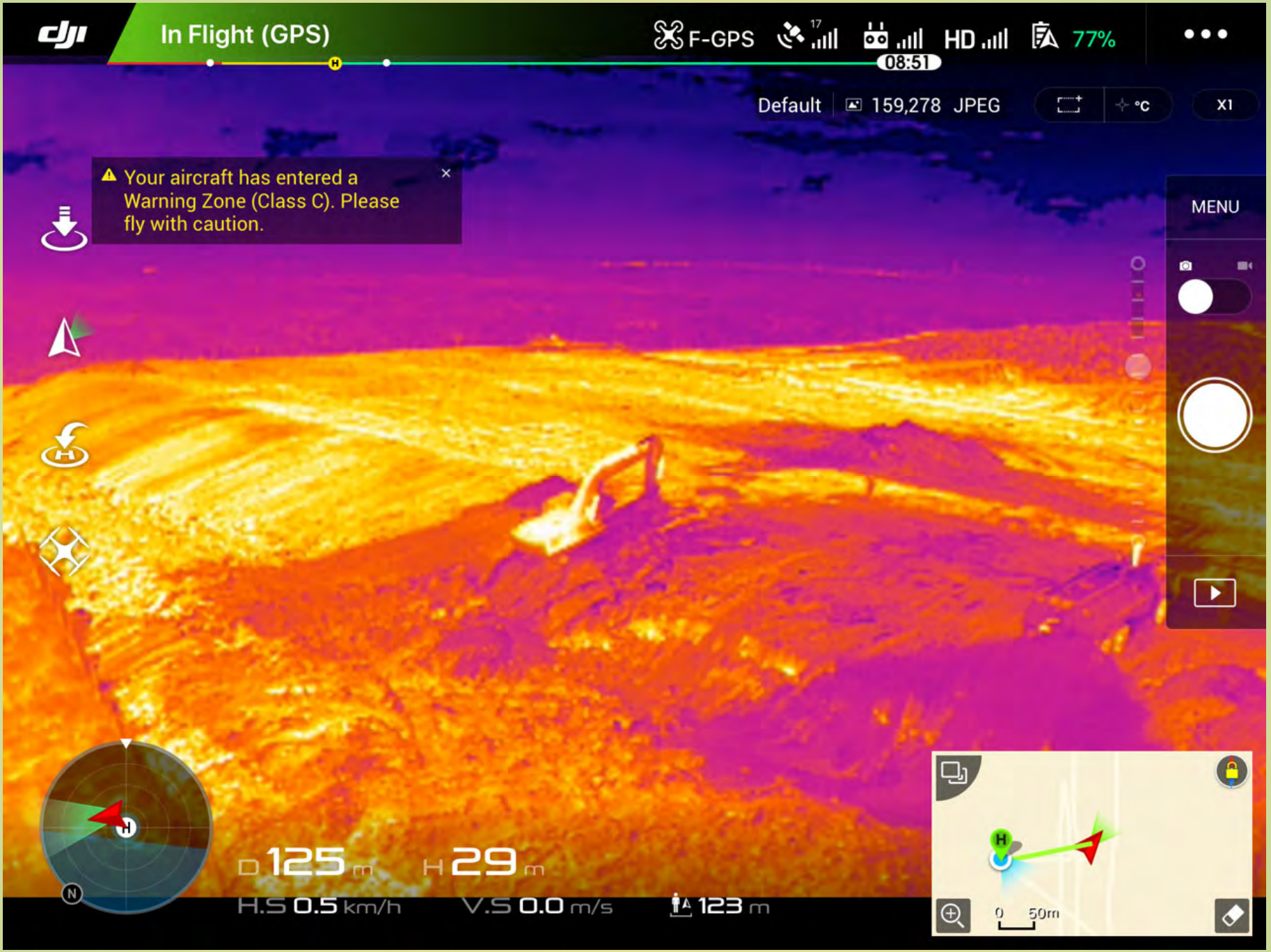
IR Scan Nassau Landfill, Bahamas



Hot Spot – Nassau Landfill, Bahamas

Helicopter with Infra-Red Camera

Infrared Drone Capacity



IR Drone gives real time fire status

Production Drilling at Delta Shake

Drilling Rig – Use Hollow Stem Auger or Sonic.

Note health and safety precautions.

Installing Thermister Cable at Minnesota DLC Site.

Installing Thermistors

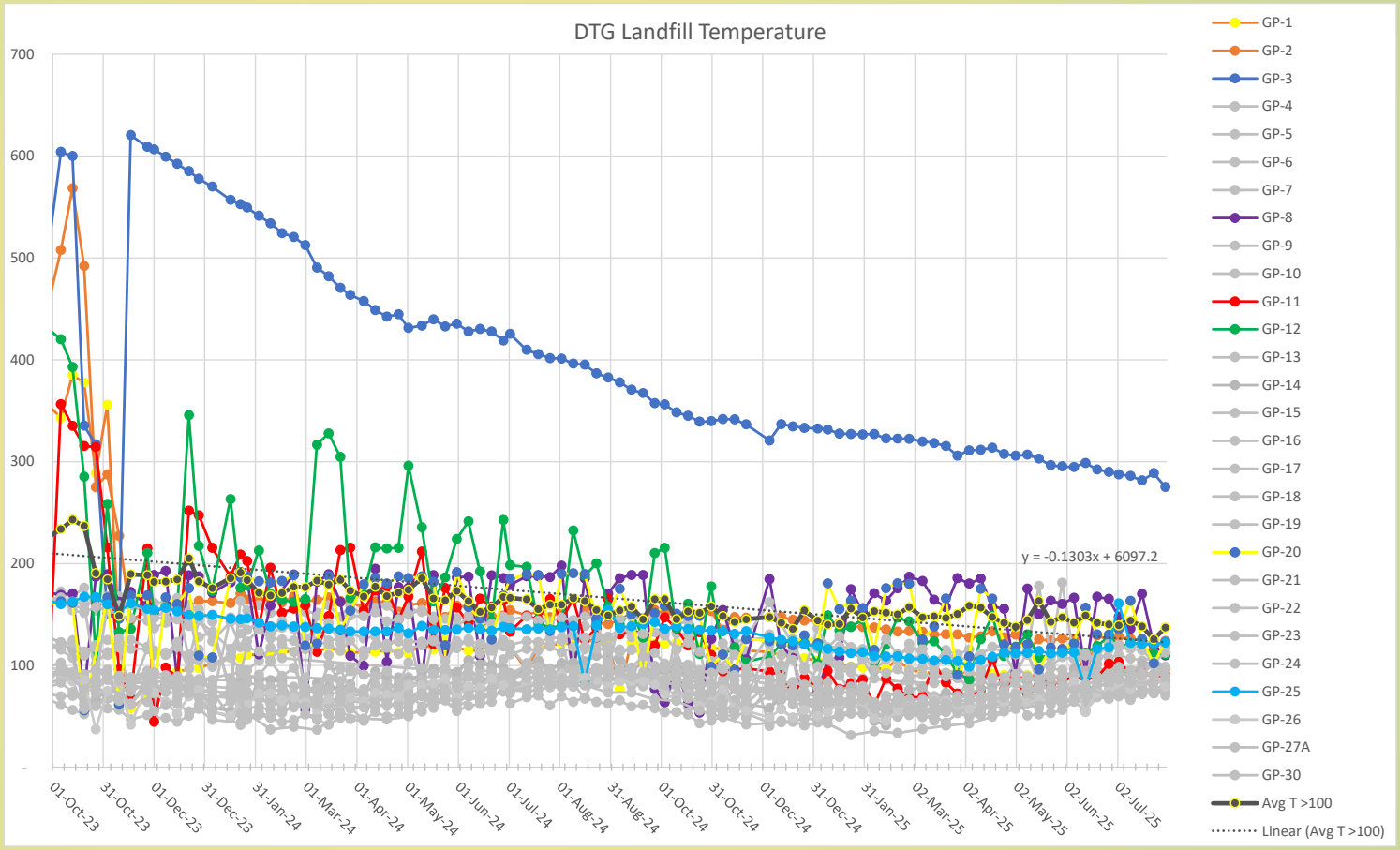
Thermistor Assembly

Melted PVC stand-pipe.


LANDFILLFIRE.com
High Temp
High CO
High H2S
High VOC
Existing GPs
New GPs
GP-10
GP-21
GP-22
GP-23
GP-24
GP-15
5
GP-16
6
GP-17
GP-18
GP-19
GP-20
GP-25
1
GP-11
2
T2
GP-12
T1
3
GP-14
4
GP-13

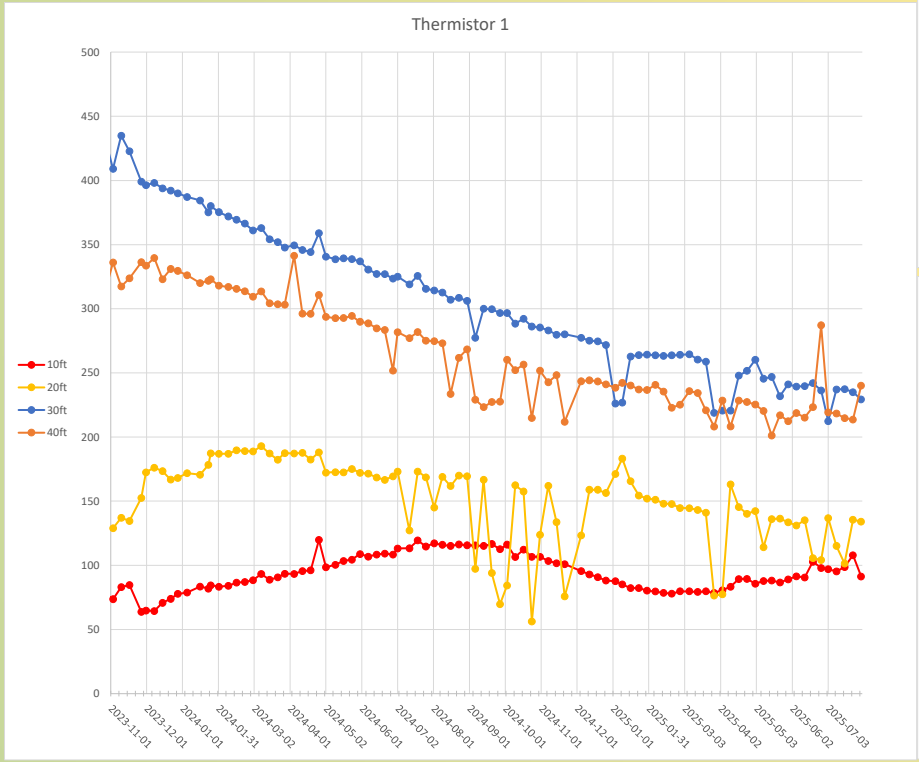
Temperature (F)

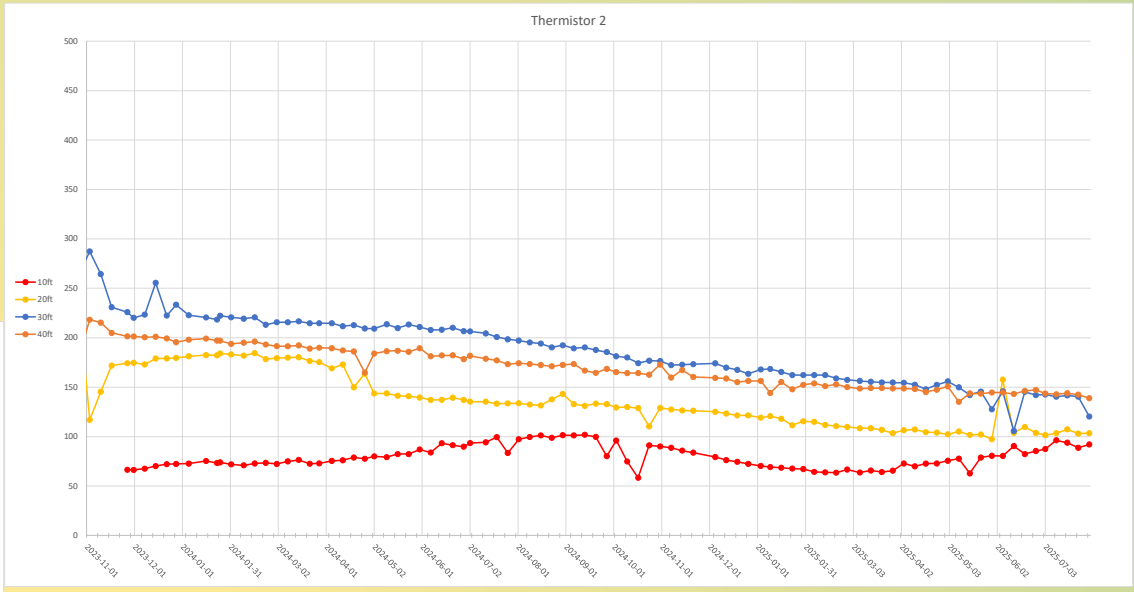
- July saw continued decreasing temperatures in GP-3, the hottest well, with temperatures continuing to fall below 300F, and the last event in July having a recorded temperature of 275F.
- Similar to June, the trend line continues to show gradual cooling, with the wells reading above 100F showing some variation but seeming to be generally stable over the past month.
- Note the seasonal warming that can be seen in the lowest temperature wells, exhibiting slightly higher temperatures during the summer months.

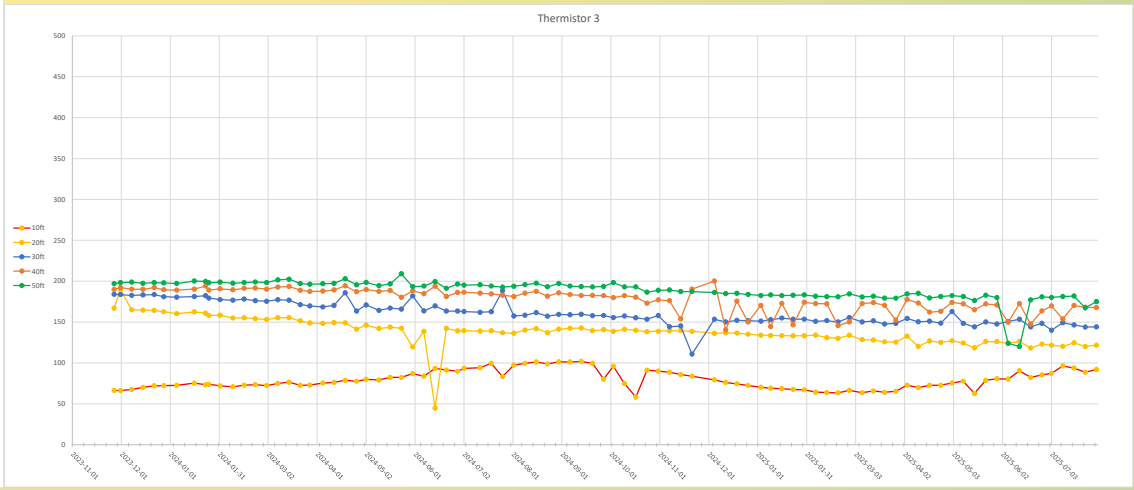


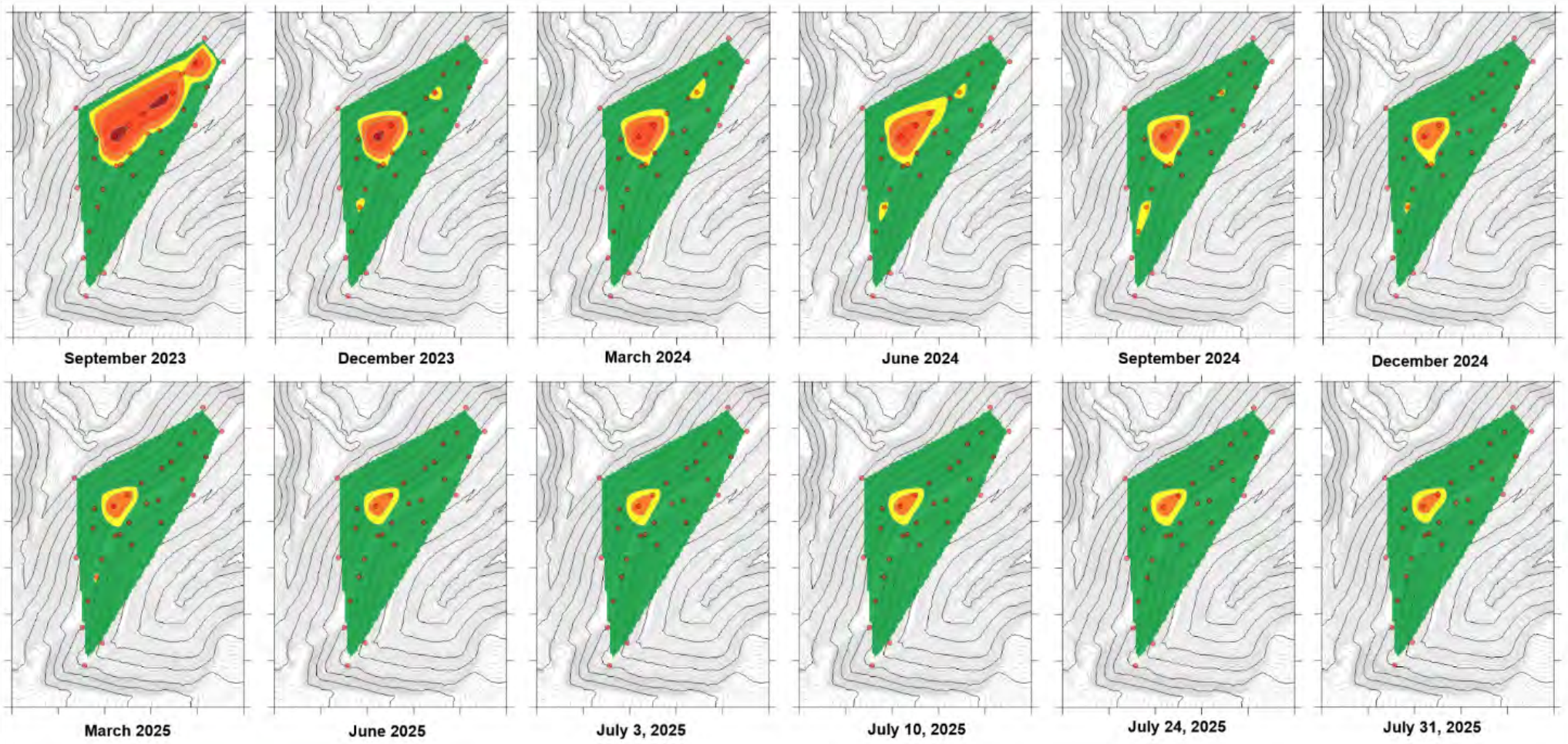
Thermistor Temperatures

- Thermistor temperatures are mostly stable, with a slight downward trend in T-1, T-2 and T-3, however; the rate of cooling is decreasing, especially in T-1. Consideration should be given to installing a dedicated thermistor on T-1 at 20 ft, as the oscillations seen at depths of 20 and 30ft feet indicate there may be issues with the measurements.
- The rapid spike up outlier data point for the 40ft depth in T-1 is noted, and SHA is not concerned as temperatures have returned to previous levels.









- Data taken from first monitoring event of each month unless noted otherwise
- Data has been interpolated between data points
- Datapoints (probe locations) represented in red
- Temperatures are measured in degrees Farenheit
- Ground contours are of existing ground at beginning of project, with design contours added for after addition of fill

No.	DATE yr/m/day	REVISIONS	DRAWN	CHK'D	APP'D

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DESIGN BY:	T. SPERLING
DRAWN BY:	M. DOORNBOS
DATE CREATED:	2025/08/07
SHA PROJECT #	LFCI-2023-001

DTG RECYCLE LANDFILL FIRE

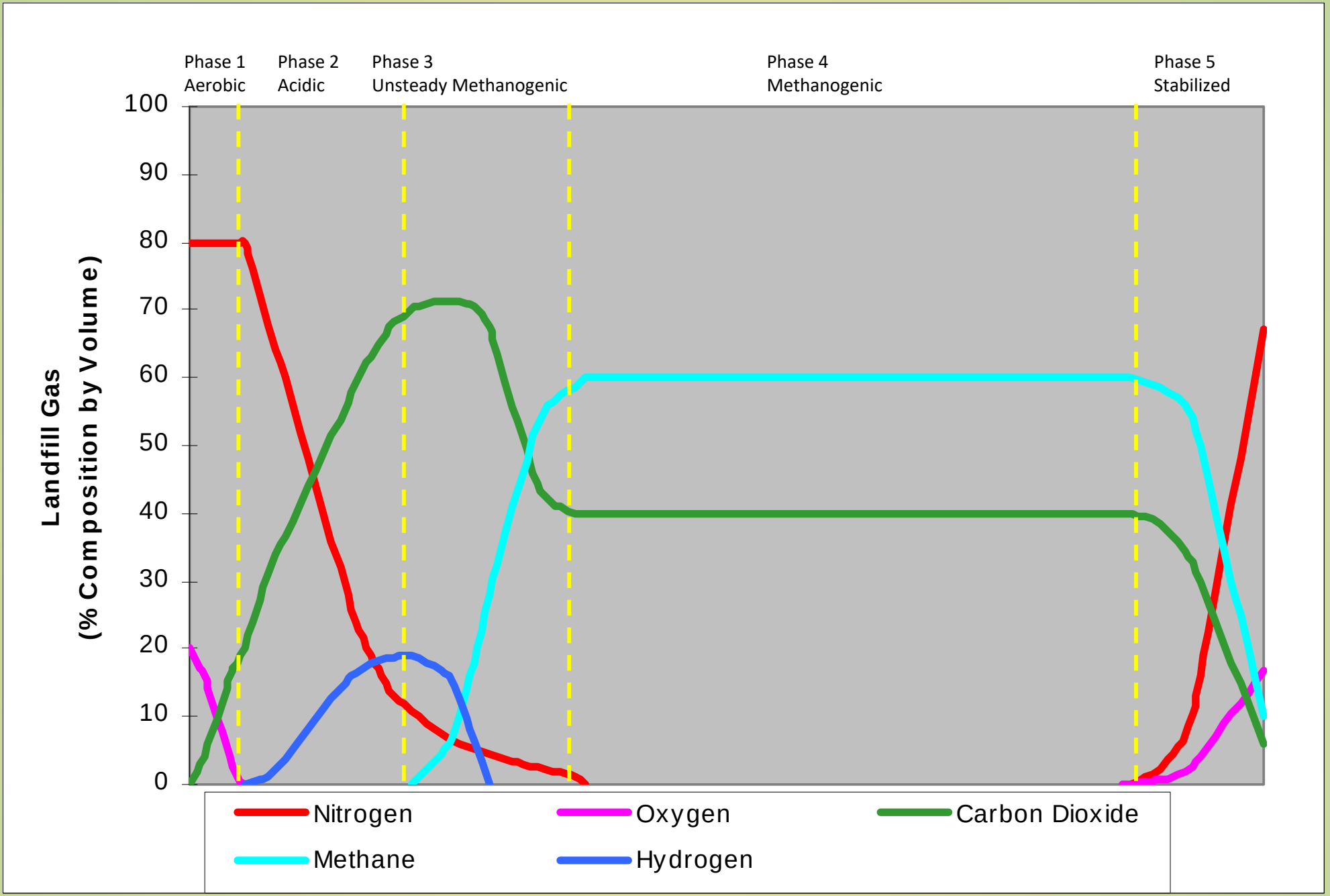
MONTHLY MONITORING SUMMARY SPATIAL MAPS - TEMPERATURE

DRAWING NO.	REV	SHEET
LFCI-2023-001-07-TEMP	1	1

Landfill Gas Composition Monitoring

- Parameters to measure.
  - Oxygen (O_2)
  - Methane (CH_4)
  - Carbon Dioxide (CO_2)
  - Carbon Monoxide (CO)
  - Nitrogen (N)
  - Hydrogen (H_2)
  - VOCs

- Active fire unlikely if oxygen not present (<1%).
- Risk of spontaneous combustion if oxygen present (>5%).
- Operate landfills in anaerobic methanogenic state.
- Aerobic bioreactors are fires waiting to happen.



Phases of Landfill Gas Production

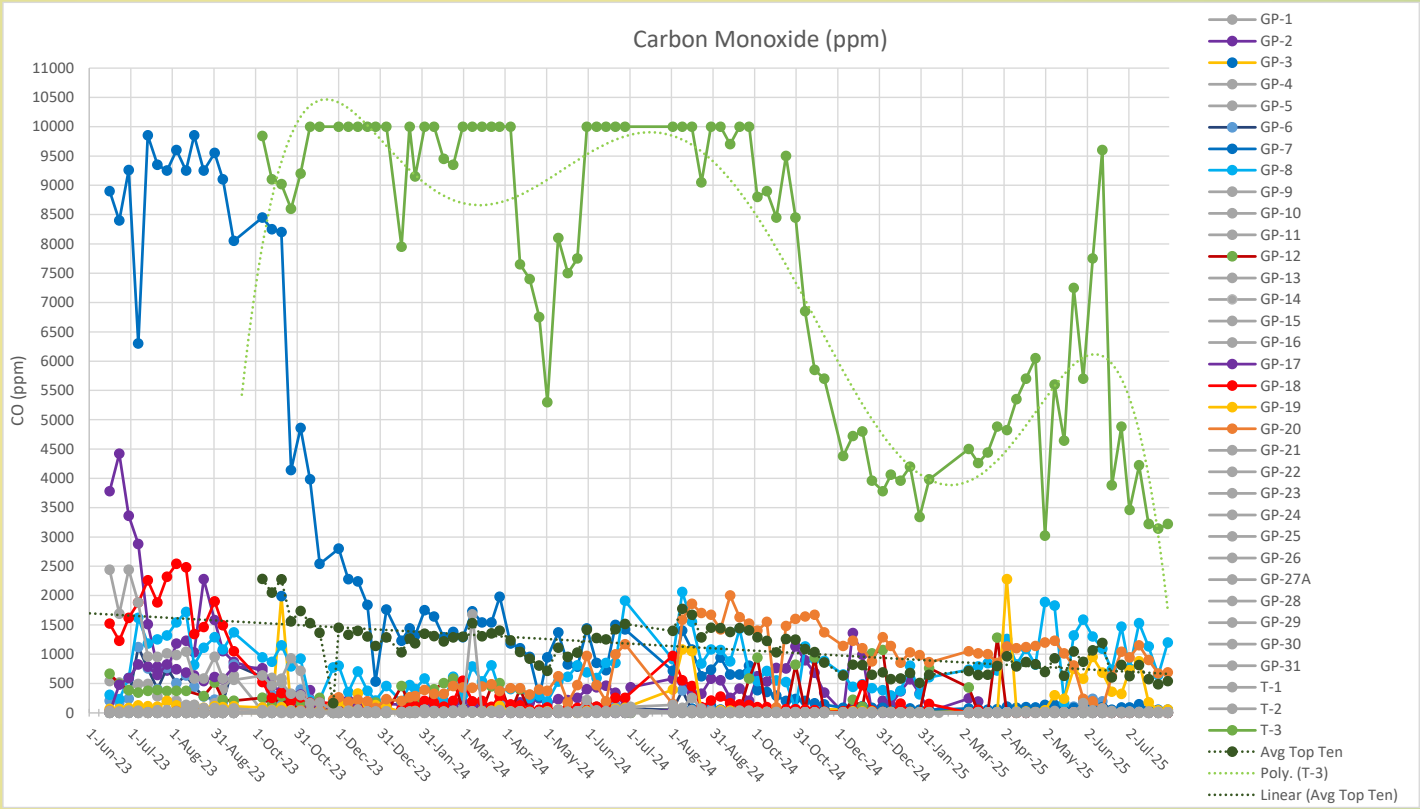
CARBON MONOXIDE CONCENTRATIONS (ppm)

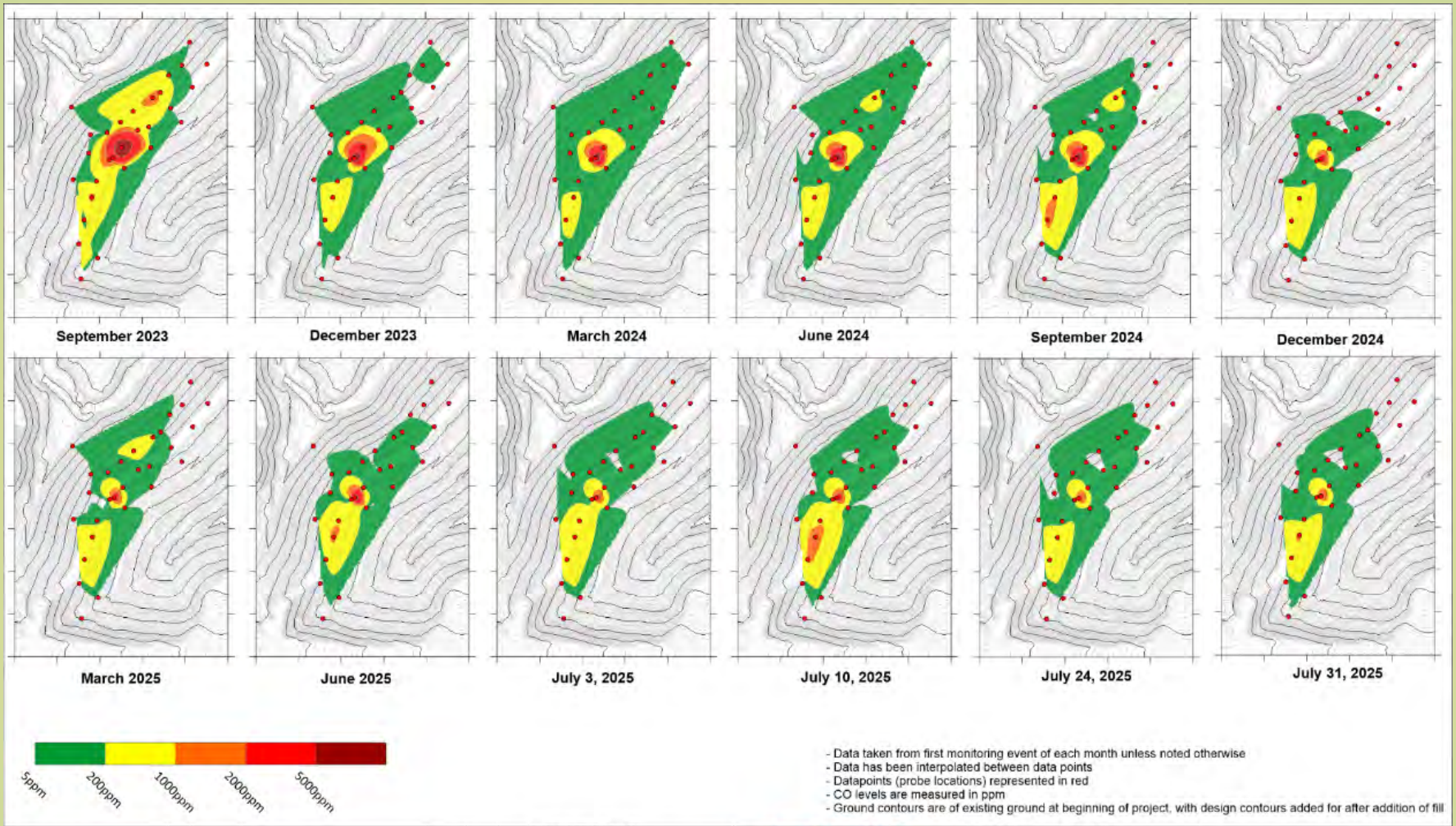
No Fire Indication	0 – 200
Possible Fire in Area	200 – 500
Potential Smouldering Nearby	500 – 750
Fire or Exothermic Reaction Likely	750 – 1000
Fire in Area	> 1000

Caution: H2S and H2 presence can affect some CO sensors, giving false positive.

Carbon Monoxide

- The month of July saw positive Carbon Monoxide trends, with levels maintained around 3500ppm in the T-3, the highest measuring well.
- The average CO across the top 10 wells has been decreasing steadily since soil application commenced, with a slight increase since January 2025, correlating with increased pressure oscillations that push more atmospheric air into the landfill. This slight increase has now returned to declining trends.




September 2023
December 2023
March 2024
June 2024
September 2024
December 2024
March 2025
June 2025
July 3, 2025
July 10, 2025
July 24, 2025
July 31, 2025
5ppm
200ppm
1000ppm
2000ppm
5000ppm
- Data taken from first monitoring event of each month unless noted otherwise
- Data has been interpolated between data points
- Datapoints (probe locations) represented in red
- CO levels are measured in ppm
- Ground contours are of existing ground at beginning of project, with design contours added for after addition of fill
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DTG Recycle
DESIGN BY: T. SPERLING
DRAWN BY: M. DOORNBOS
DATE CREATED: 2025/08/07
SHA PROJECT # LFCI-2023-001
DTG RECYCLE LANDFILL FIRE
MONTHLY MONITORING SUMMARY
SPATIAL MAPS - CO
DRAWING NO. LFCI-2023-001-07-CO
REV 1
SHEET 1

WARNING: Carbon Monoxide Measurements

- Warning: When assessing for CO, remember it is a gas that can kill you. As discussed in more detail in Health and Safety Section, the permissible long term exposure level for CO is 50 ppm. Exposure to CO concentrations above 200 ppm is unhealthy and exposure to CO concentrations above 1,000 ppm can kill you.

Toxic Gas Results

- **Number of chemicals in ppm range**
- **Known/suspected carcinogens**
- **Health and Safety awareness**

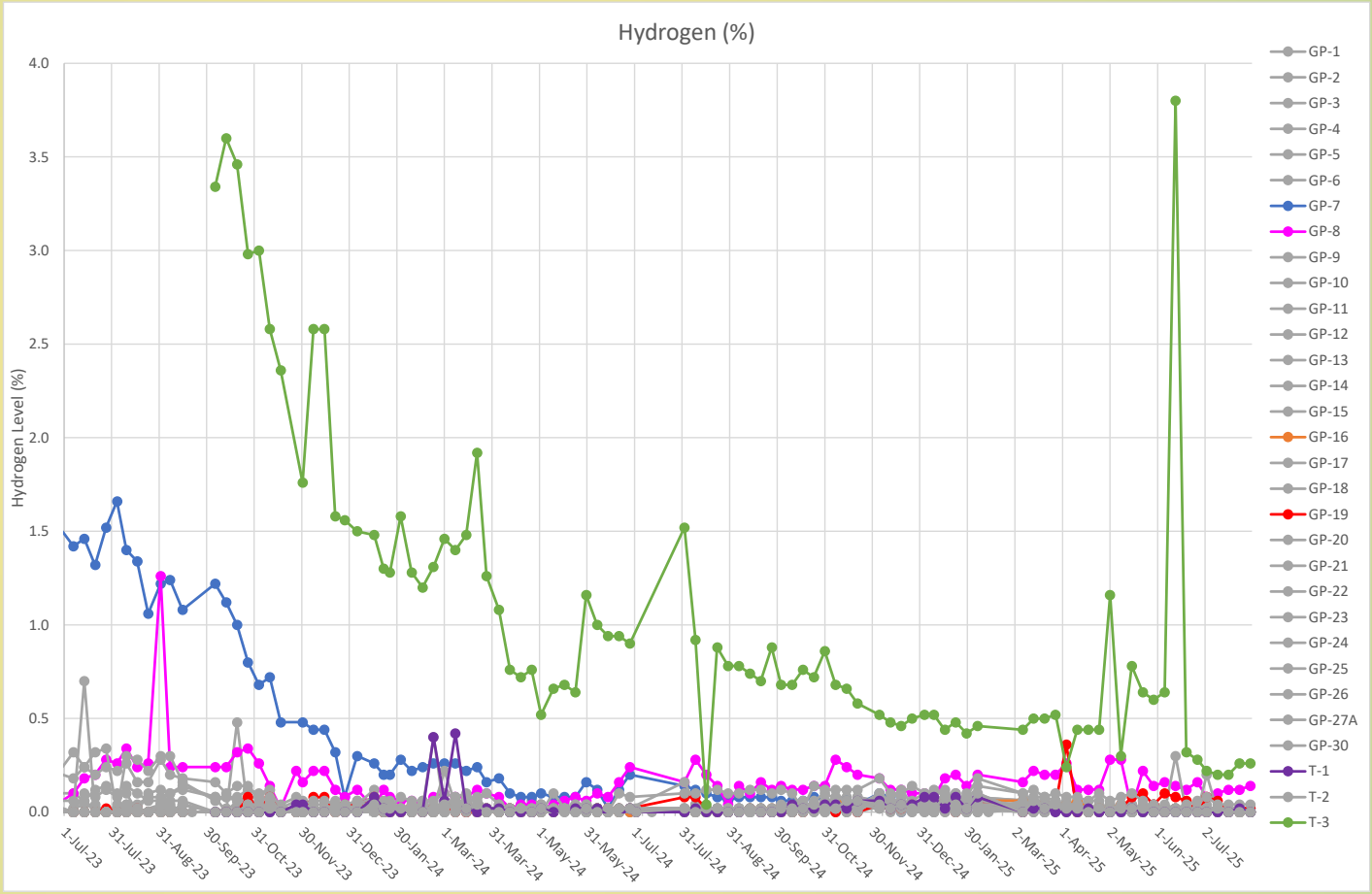
Table 5. Toxic Organic Results for the Lone Pine Landfill

TO-14 Results (in ppb v/v)				
	Sample			
Parameter	**LPL-2**	**LPL-3**	**LPL-5**	**LPL-7**
Chloromethane	86100[E]	ND	74300	4.7
1,2-Dichloro-1,1,2,2-Tetrafluoroethane	ND	ND	ND	12.1
Chloroethane	780	ND	900	38.7
Trichlorofluoromethane	1760	ND	1600	66.2
Acetone	ND	552[E]	363000[E]	ND
Methylene Chloride	ND	ND	ND	23.2
1,1,2-Trichloro-1,2,2-Trifluoroethane	ND	1.1	ND	6.4
Carbon Disulfide	1080	2.2	1300	ND
1,1-Dichloroethane	ND	ND	ND	54.9
Vinyl Acetate	ND	13.2	ND	285
2-Butanone	61900	441[E]	49100	81.3
1,2-Dichloroethane	430	ND	1600	ND
1,1,1-Trichloroethane	ND	ND	ND	141
Benzene	21900	ND	9100	5.3
4-Methyl-2-Pentanone	ND	175	ND	ND
1,2-Dibromoethane	ND	ND	22900	9.8
Trichloroethene	ND	ND	8400	14.7
Tetrachloroethene	ND	ND	18200	ND
Ethylbenzene	5870	ND	800	3.2
1,1,2,2-Tetrachloroethane	ND	ND	1200	ND
Xylenes (Total)	40600	ND	2300	11.5
4-Ethyltoluene	7710	ND	ND	ND
1,3,5,-Trimethylbenzene	2800	ND	ND	ND
1,2,4-Trimethylbenzene	7730	ND	ND	3.4
Hexachloro-1,3-Butadiene	460	ND	1400	ND

Notes: ND - Non Detect at reporting limit
E - Estimated Value. Concentration exceeded the calibration range. Actual concentration may be greater

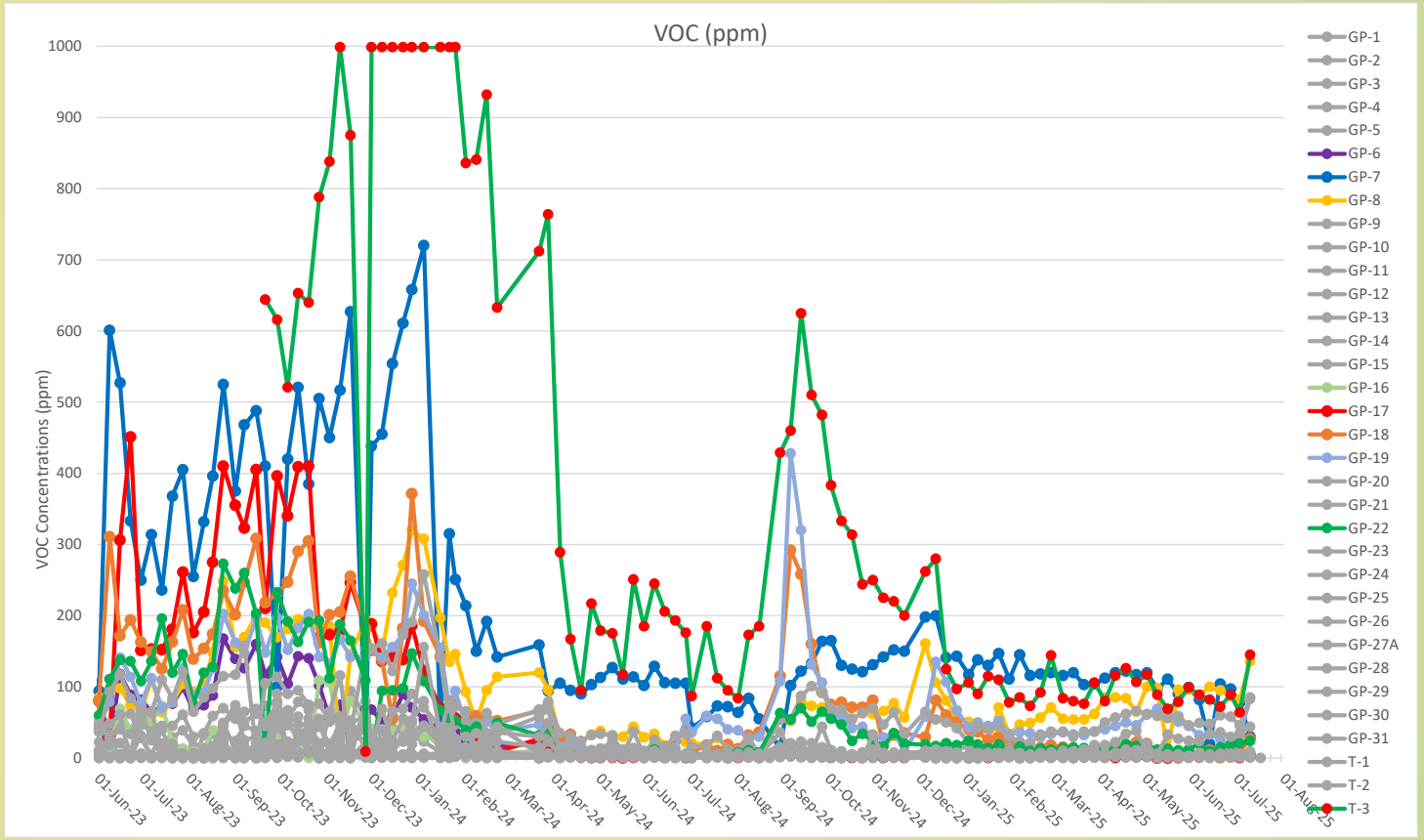
Hydrogen

- The hydrogen measurements in T-3 have continued at an all-time low, around 0.25%.
- Hydrogen remains very low in all other wells. Production of H_2 is often observed with smoldering waste. LFCI believes that the level of H_2 dropping continues to indicate that the fire is less active.



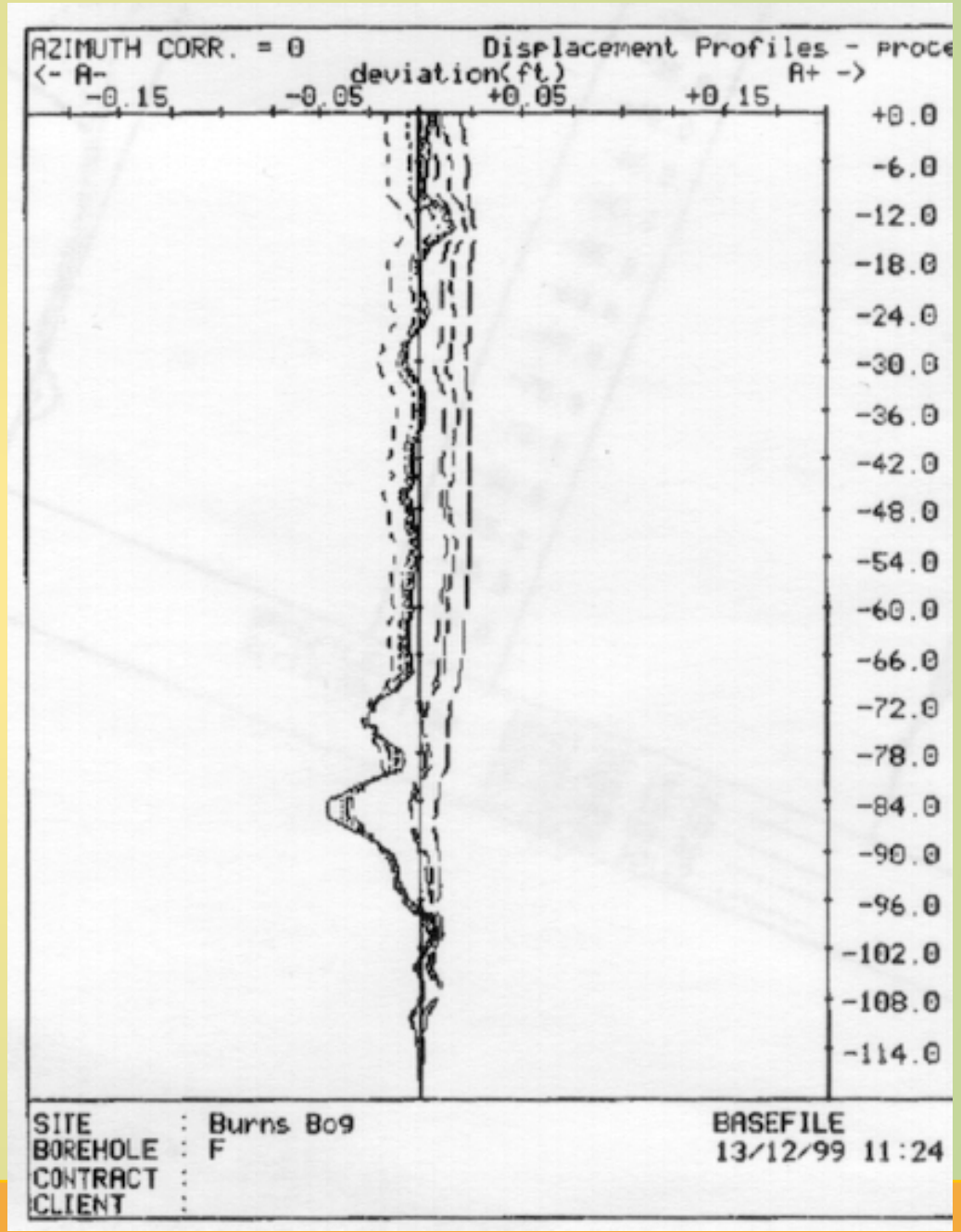
Volatile Organic Compounds

- Through June and the first monitoring event of July, VOC levels have continued a modest declining trend with the highest concentrations in several wells around 100ppm.
- VOC emissions are often related to subsurface landfill fires. The fact that VOC emissions have declined and stayed low for the past several months are a strong indication that the fire is inactive.
- Slight increase in VOC's following July 1 air incursion event is indicative of increased smoulder activity.



Geotechnical Monitoring

- Essential if landfill stability is an issue.
- Total station monitoring of fixed targets is effective.
- Slope inclonometers provide indication of slope movement.
- Crack measurements or wire limit switches can be used to monitor cracks.
- Piezometers measure leachate mounding.



Slope Collapse, Roatan Landfill, Honduras

Dr. Tony Sperling, P.Eng.

Section 4 Review:

Anaerobic decomposition stops above temperatures of:

a) 60C or 140F
b) 75C or 149F
c) 167C or 300F
d) 316C or 600F

Smelling vents is not recommended because:

a) H_2S could be present
b) CO_2 could be present
c) NOx could be present

A fire is definitely occurring if subsurface CO readings are above

a) 100 ppm
b) 500 ppm
c) 1,000 ppm

Section 4 Review:

Key gases that should be monitored during a landfill fire are:

a) CO_2, H_2, H_2S

b) CH_4, CO_2, N_2, O_2

c) CO, O_2, H_2, VOC

d) H_2S, O_2, CH_4, LEL

END OF SECTION 4