Storm Drain Pond Washout Study

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Source of SDP Activity

- Precipitation Washout?
  - Scavenging by Rain
- Atmospheric Condensation?
  - Dew Point Condensation in Atmosphere and Subsequent Scavenging by Droplets
    - Effluent Plume
    - Cooling Tower Plume
- Surface Condensation?
  - Condensation Upon Contact With Surface
- Release of Rad Waste Water Into Storm Drains?

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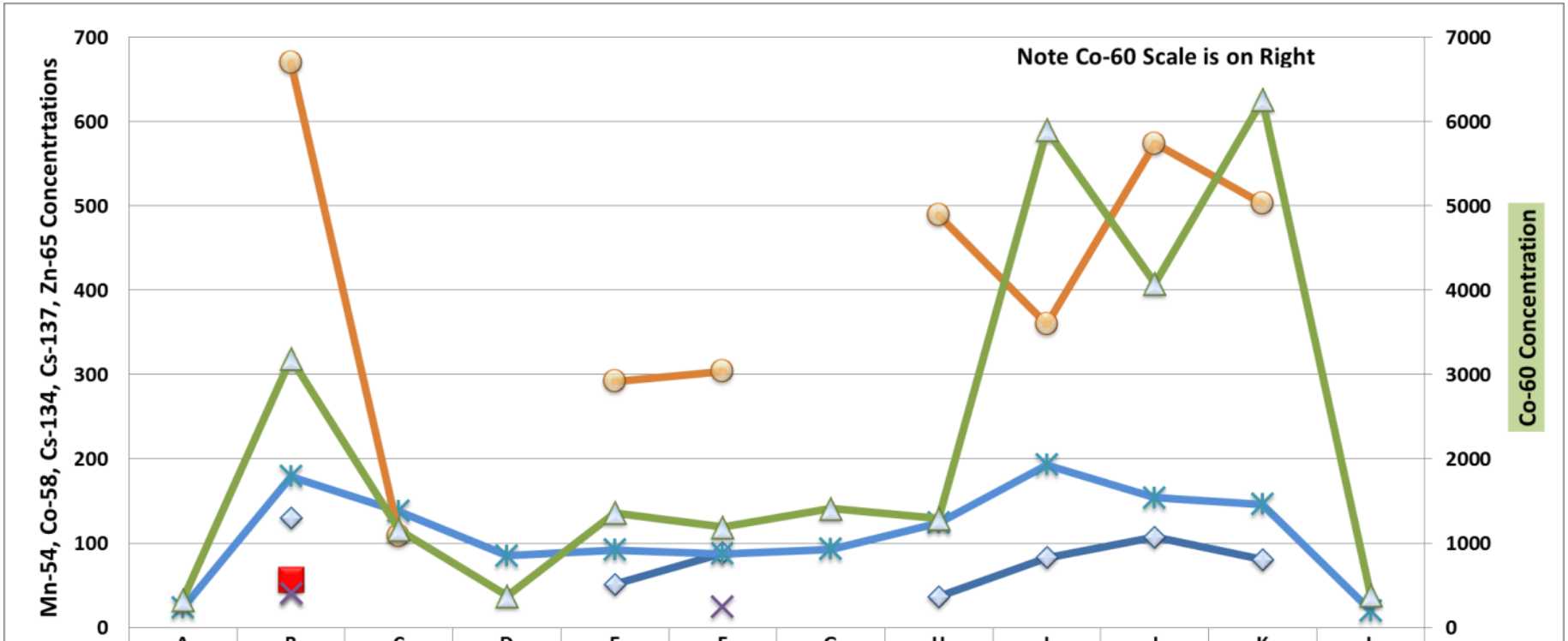
SDP Soil Concentrations (pCi/kg)



	A	B	C	D	E	F	G	H	I	J	K	L
Mn-54		130			51.3	88.5		36.7	83	107	80.3	
Co-58		57										
Cs-134		41.3				23.9						
Cs-137	23.0	179.0	138.0	85.0	91.8	87.2	93.0	124.0	193.0	154.0	146.0	20.0
Zn-65		670	109		292	304		489	360	574	503	
Co-60	330.0	3190.0	1160.0	375.0	1360.0	1190.0	1410.0	1290.0	5900.0	4080.0	6260.0	382.0

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Sampling Locations

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Keep It Simple

- Examine Various Scenarios for Validity
  - Rain Washout
  - Plume Precipitation
  - Scavenging By Cooling Tower Condensation or Drift
  - Unmonitored Condenser Water Discharge to Storm Drain
- Are Listed Scenarios Credible?
- Can Scenarios Be Eliminated?
- Can Positive ID of SDP Activity Source Be Made?

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Precipitation Scavenging

- Models Exist for Precipitation Scavenging for Long Term Modeling
  - Not Appropriate for CGS
- Short Term Modeling Requires More Information
  - Rain Rose
    - Wind Direction During Precipitation Events
  - Rain Spectrum
    - Rain Droplet Size Distribution
  - Height of Tropospheric Mixing Layer

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Met Data Clues

- Look at Temperatures
  - Condensation at Dew Point?
- Look at Wind Roses
  - Wind Speed Distribution by Compass Points
- Look at Rain Rose
  - Wind Rose Only for Periods of Precipitation

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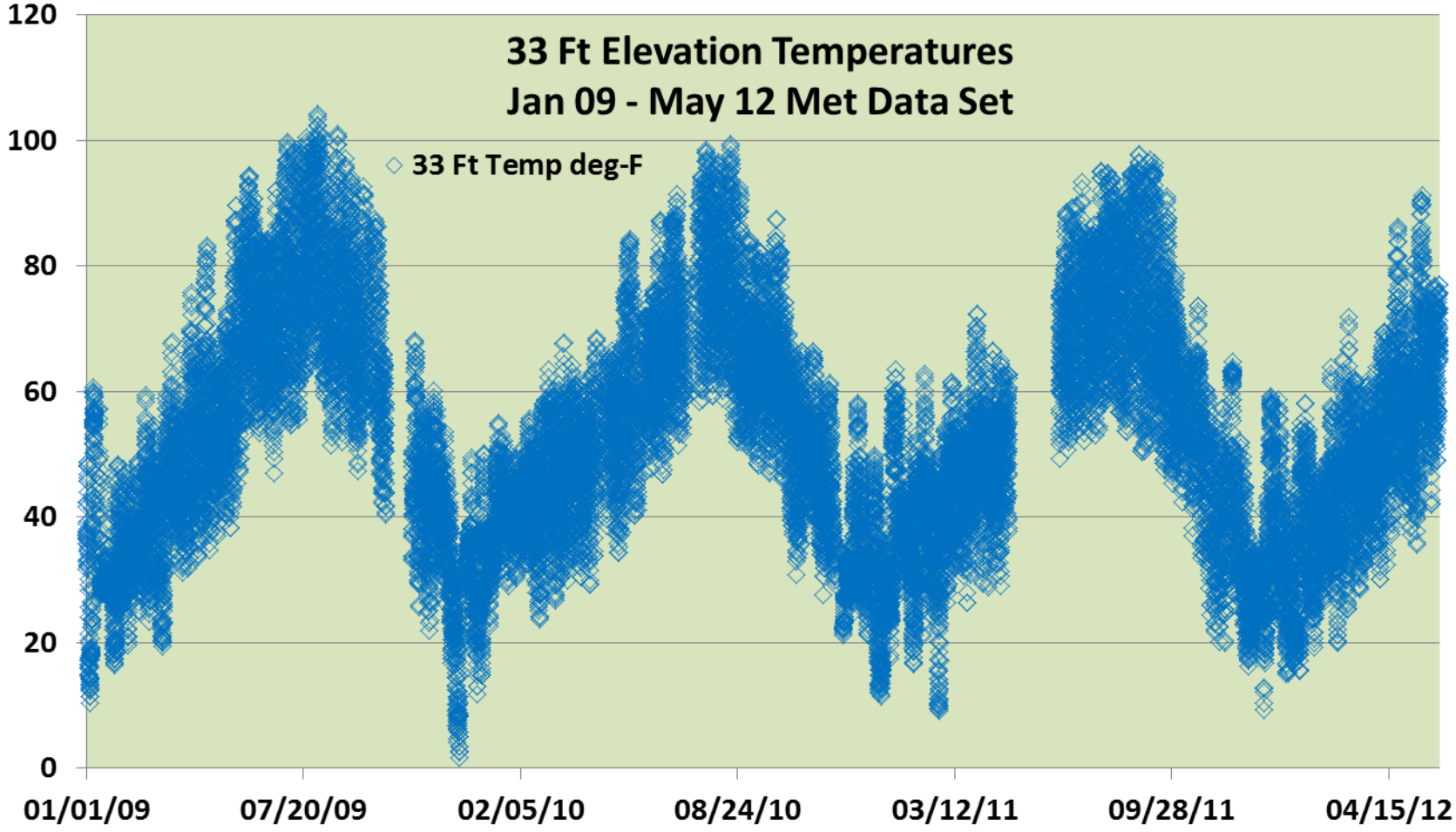
Met Data Set Review



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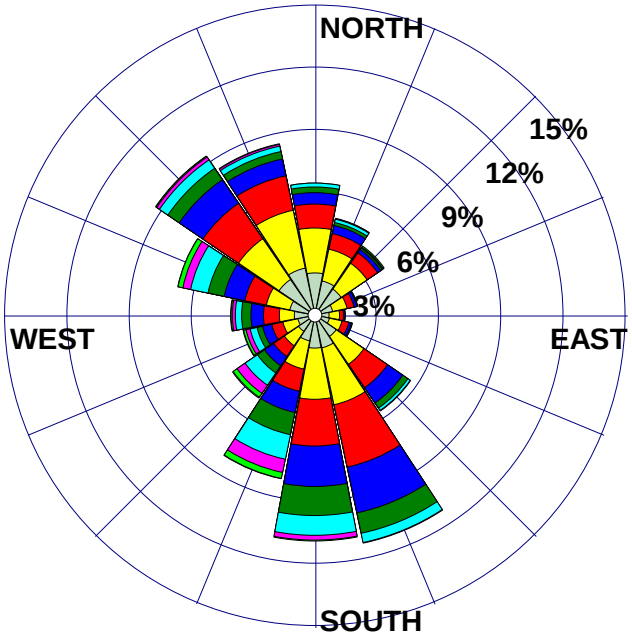
Wind Rose Data

- Plot Wind Class Frequency by Direction
- Direction Indicated by Wind Rose is the Direction the Wind is Coming *From*



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Wind Rose Data

- Overlay Wind Rose on Site Map
  - Clues For Likely Deposition Areas
- Expect 33 Ft / 245 Ft Wind Rose Difference - But Not Substantial
- Expect See Greater Difference With Rain Rose
  - Meteorology Is Obviously Different During Precipitation Events

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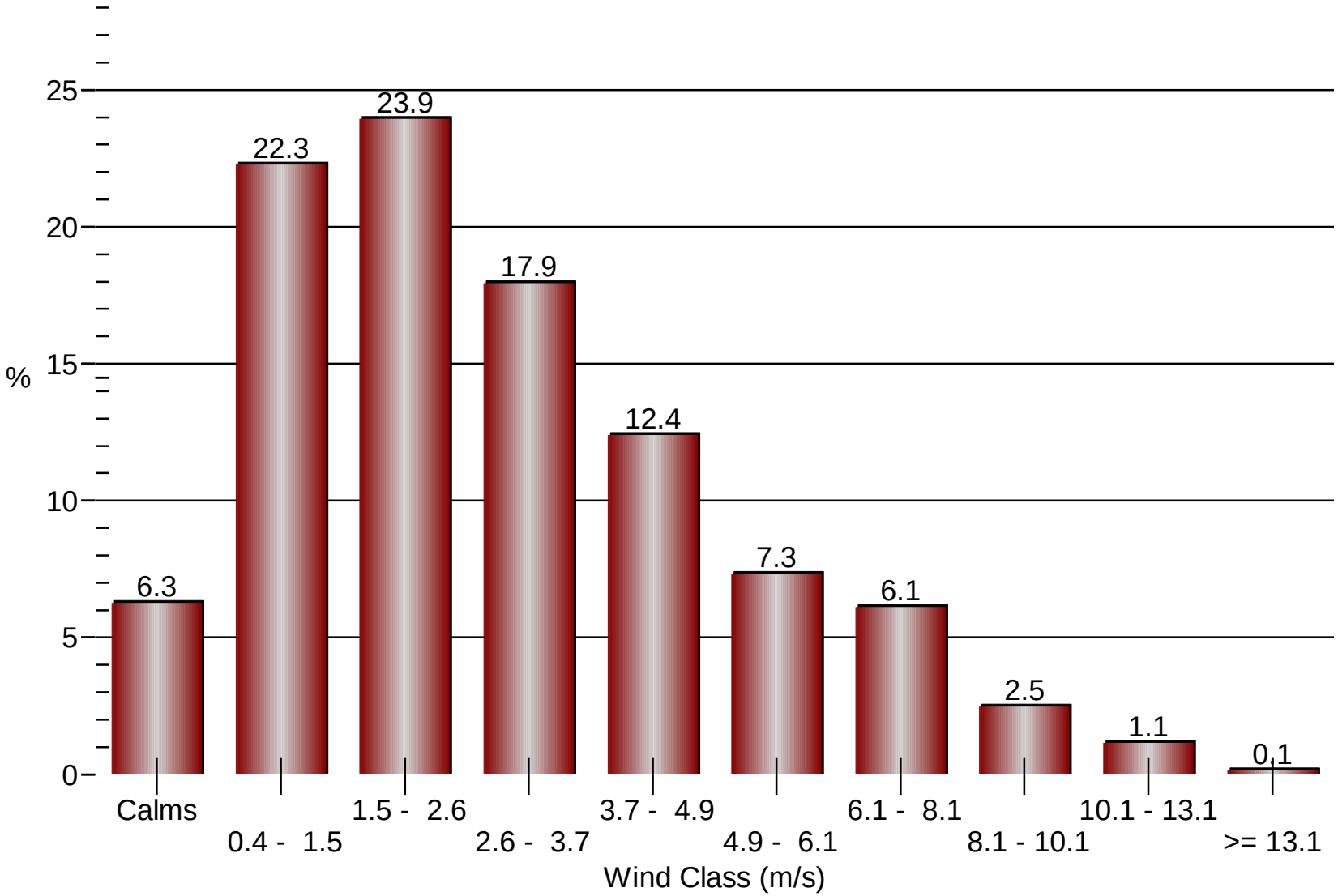
33 Ft Wind Class Frequency Distribution

Jan 09 - May 12 Met Data Set



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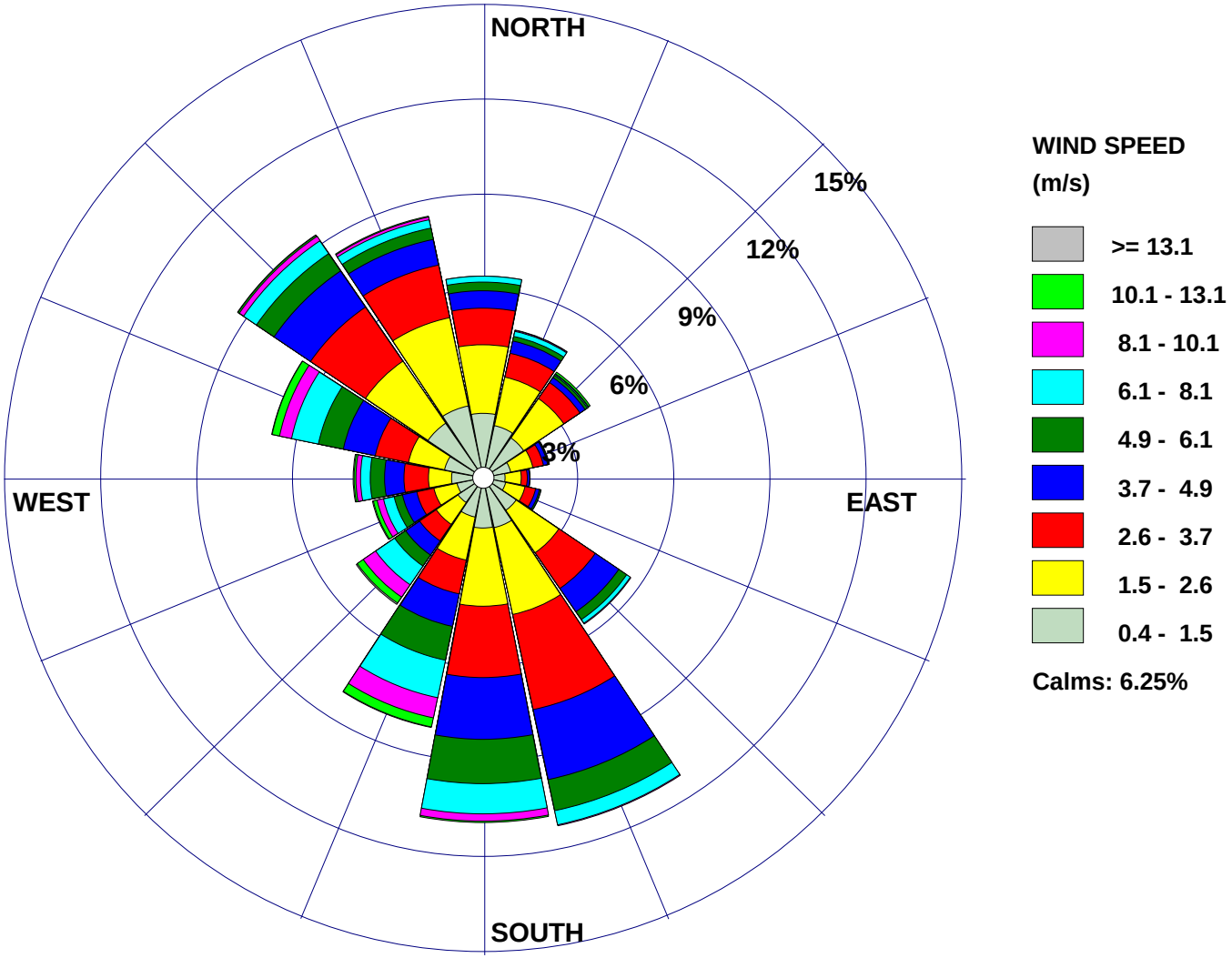
33 Ft Wind Rose

Jan 09 – May 12 Met Data Set



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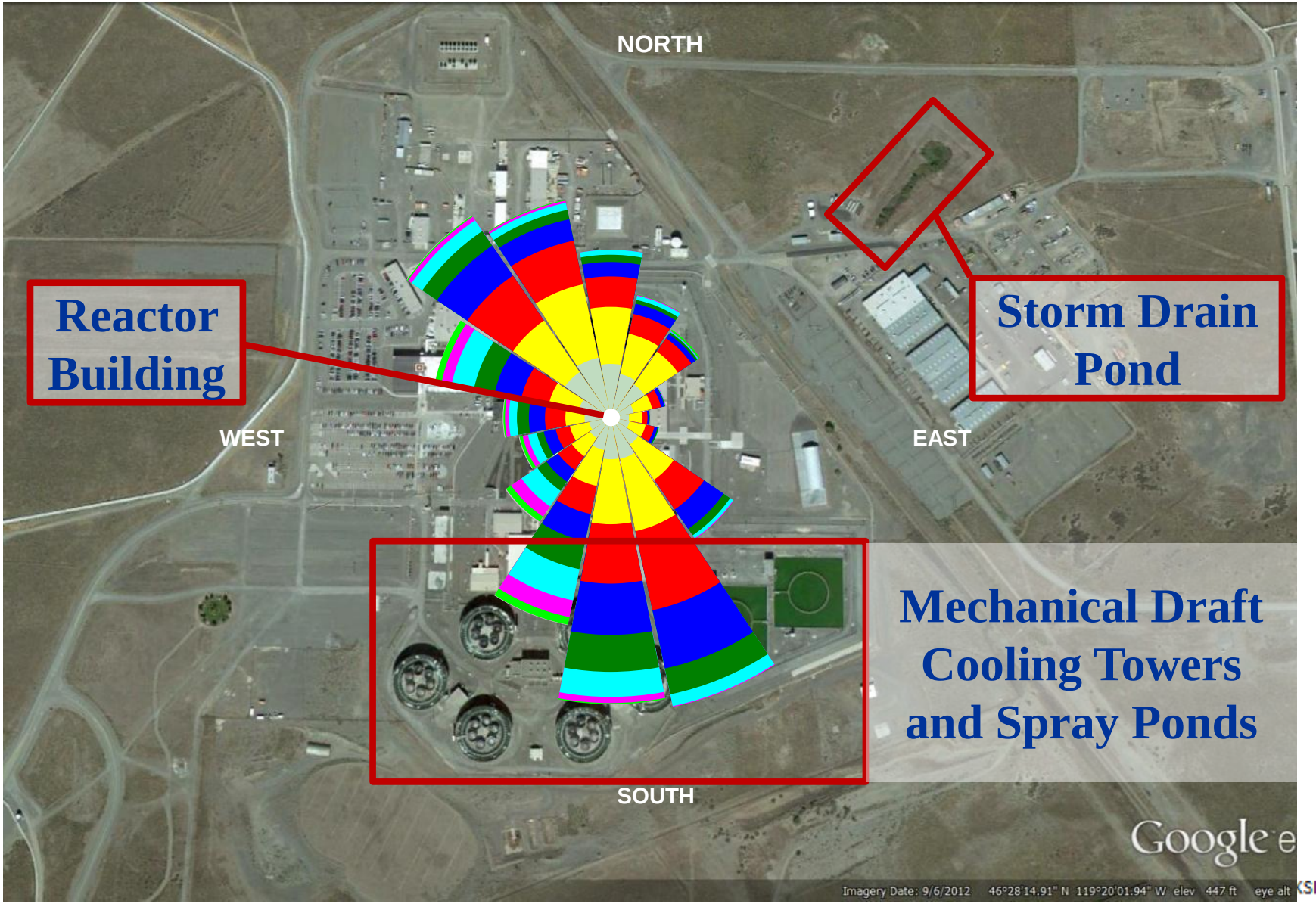
33 Ft Wind Rose - Overlay of Site



Rain Rose

- Extracted Met Records for Periods of Precipitation
  - Any precipitation less than 1/100 of an inch was ignored.
  - Rain Rose Indicates Highest Potential Washout Deposition Generally in NW and SE Sectors.

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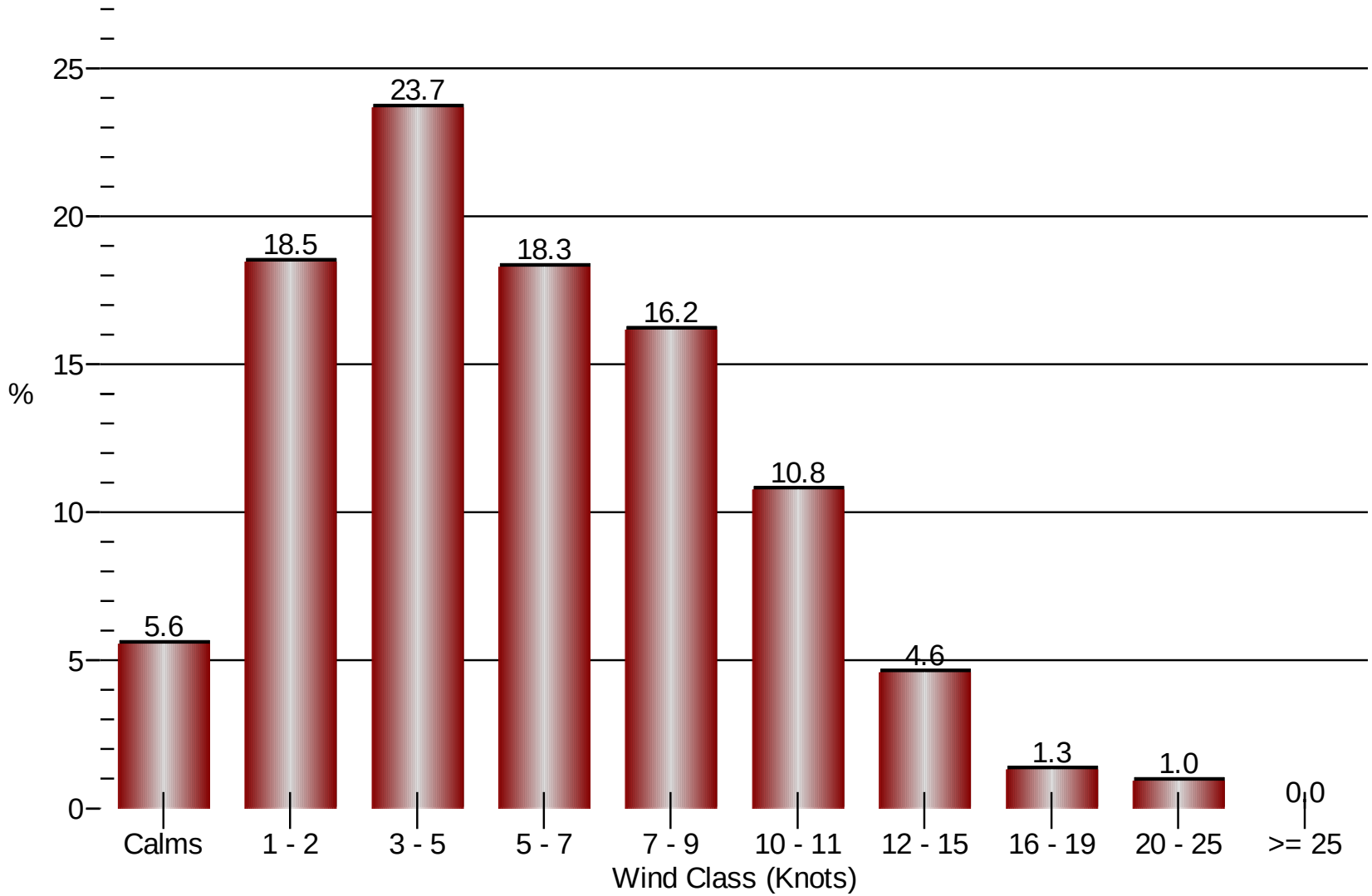
Precipitation Wind Class Frequency Distribution

Jan 09 - May 12 Met Data Set



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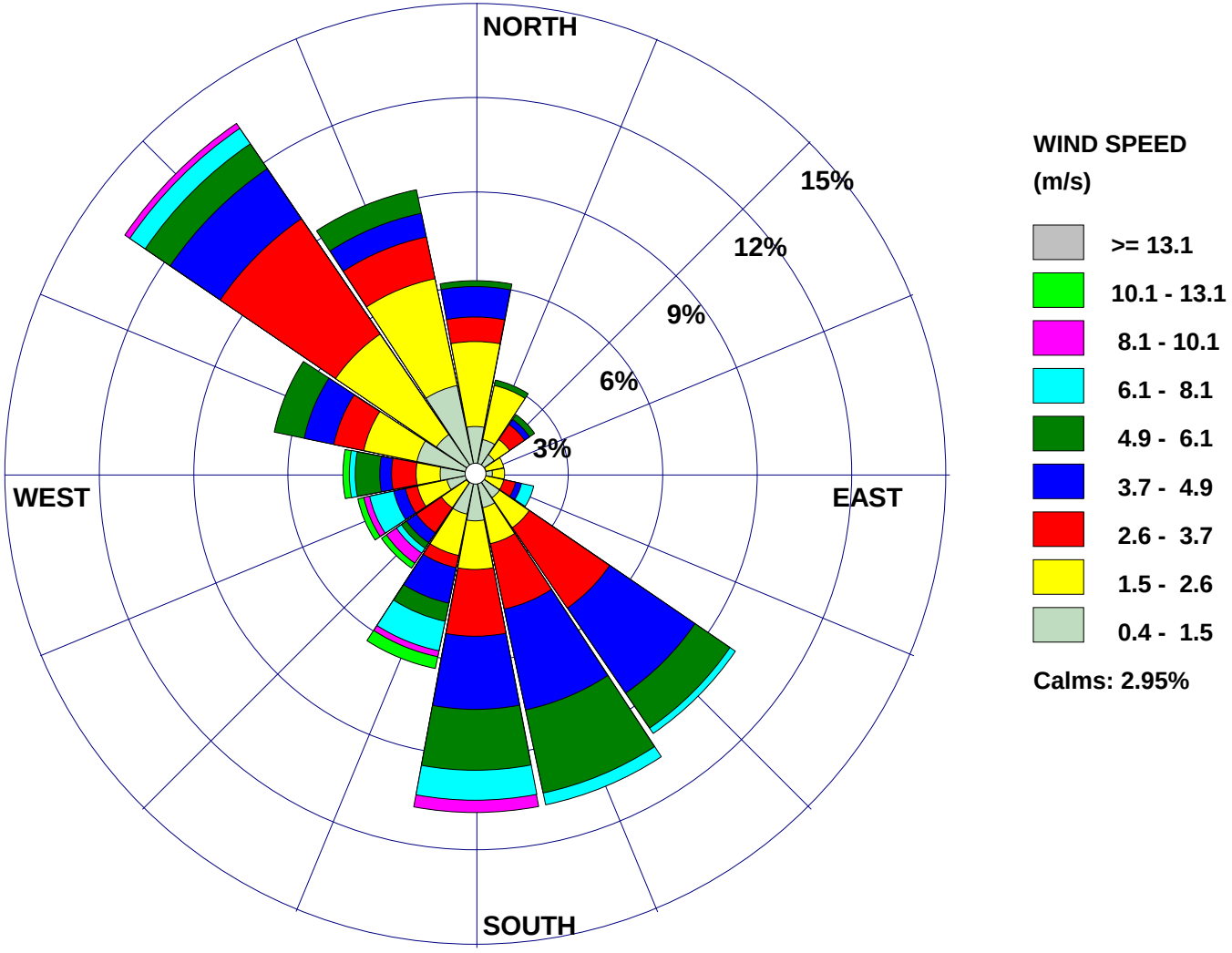
Rain Rose

Jan 09 – May 12 Met Data Set



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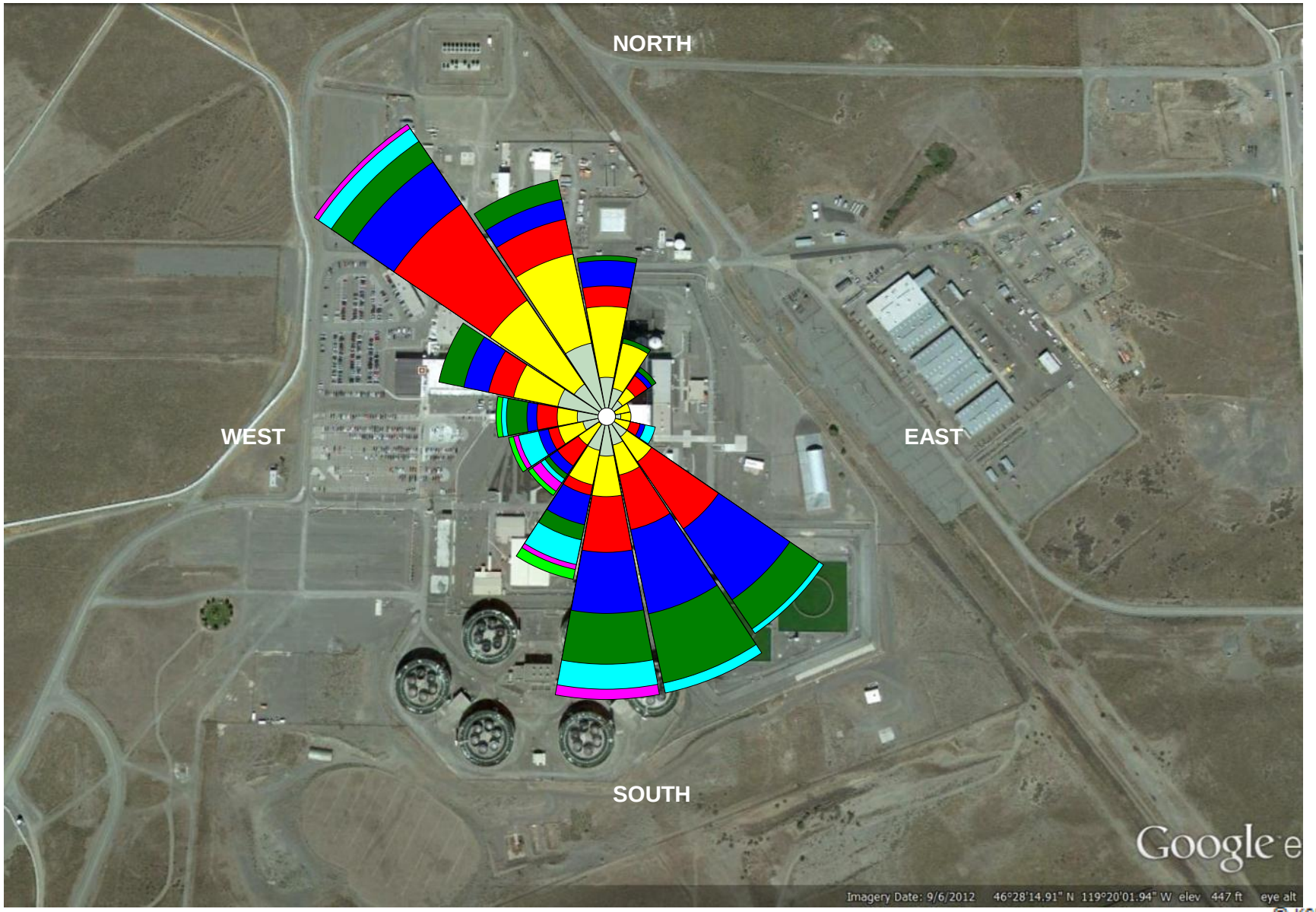
Rain Rose – 33 Ft



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Precipitation Scavenging

- Long Term Washout Factors
  - Mass Washout Factor: kg_{air}/kg_{rain}
    - Water Vapor ~ 60
    - Insoluble Particles ~ 300
    - Soluble Particles ~1000
    - Cs-137 ~ 500
  - Volumetric Washout Factors: m^3_{air}/ m^3_{rain}
    - Water Vapor ~ 10^4 - 10^5
    - Insoluble Particles ~ 10^5
    - Soluble Particles ~ 10^6
    - Cs-137 ~ $10^5 – 10^6$
- Potential For High Concentrations in Rain Water

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Precipitation Scavenging

- Strongly Temperature Dependent
- Resultant Concentrations in Environmental Samples Are Less Than Predicted By Washout Factors Due To Dilution from Rainfall Runoff
- Examine Timeline of Release and Precipitation Events

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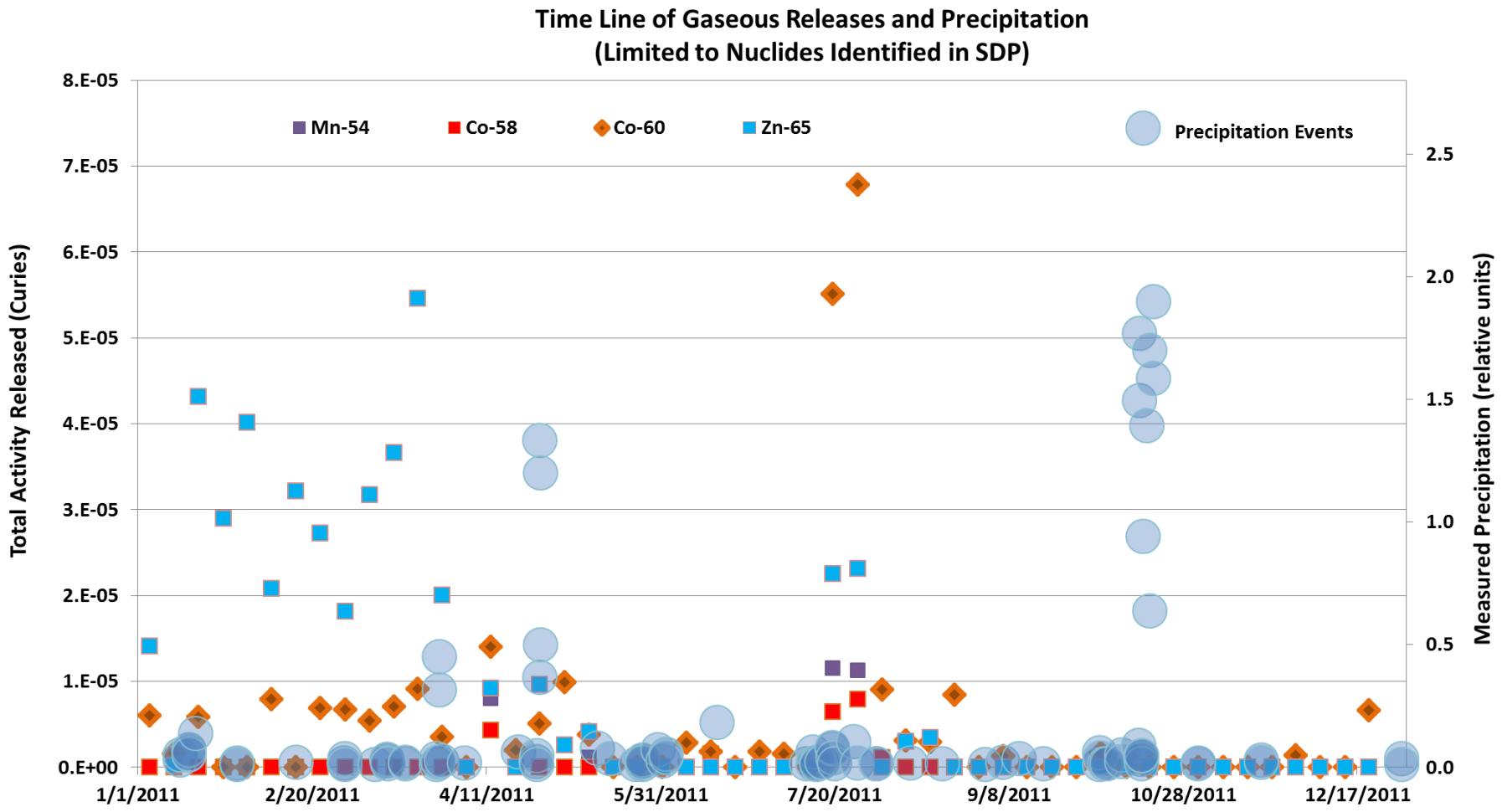
Gaseous Releases and Precipitation Events

(Limited to Nuclides Identified in SDP)



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Precipitation Events

- CGS Location Receives Little Rainfall
  - Highest Potential Occurs When Releases to Atmosphere Coincide With Precipitation Events
  - Release and Met Data Indicates Little Potential for Rainout of Nuclides of Interest
    - Co-58, Co-60, Mn-54, Zn-65

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Effluent Plume Moisture Condensation

- Airborne Plume is Typically Much Warmer Than Atmosphere
- Cooling of Plume
  - Plume Temperature and Relative Humidity Determine the Dew Point for Plume Moisture
  - As Plume Enters Atmosphere It Can Cool To Dew Point
  - Condensation in Plume May or May Not Be Visibly Seen

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Plume Moisture Condensation

- Condensation From Plume Can Provide Mechanism for Scavenging
  - Tritium
  - Radioiodines and Particulates
- Can Deposit On
  - Ground
  - Structure Surfaces

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Plume Condensation

- Plume Characteristics
  - Temperature Range
    - 25-30 deg-C
  - Relative Humidity Range
    - 10-15 percent Relative Humidity
- Calculate
  - Max and Min Dew Point Temperatures
- Compare Plume Dew Point and Atmospheric Temperatures

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Dew Point Calculation

- Saturation Vapor Pressure (Pv)
  - Determined Using Clausius-Clapeyron Equation
  - Function of Temperature
- Partial Pressure (Pp)
  - Derived From Relative Humidity
- Dew Point is Temperature at Which:

$$Pv = Pp$$

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Meteorology and Plume Dew Point

- Temp vs Time
  - 33 meter temperature
- Dew Point Band Overlay
  - Effluent Temp Range: 25 to 30 deg-C
    - Based on Plant Data
  - Effluent Rel Humidity (RH) Range: 10% to 15%
    - Assumed to be conservative
- Dew Point Temps
  - 10% RH @ 25 deg-C = 16.8 deg-F
  - 15% RN @ 30 deg-C = 33.7 deg - F

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Met Data and Dew Point

- Plots Show Historical Temperatures at 33 Foot Level
  - If plume is cooled by atmosphere to dew point then condensation occurs.
- Historical Data Shows
  - Plume condensation possible large fraction of time during cool weather
  - Atmospheric Temp < 33.7 deg - F

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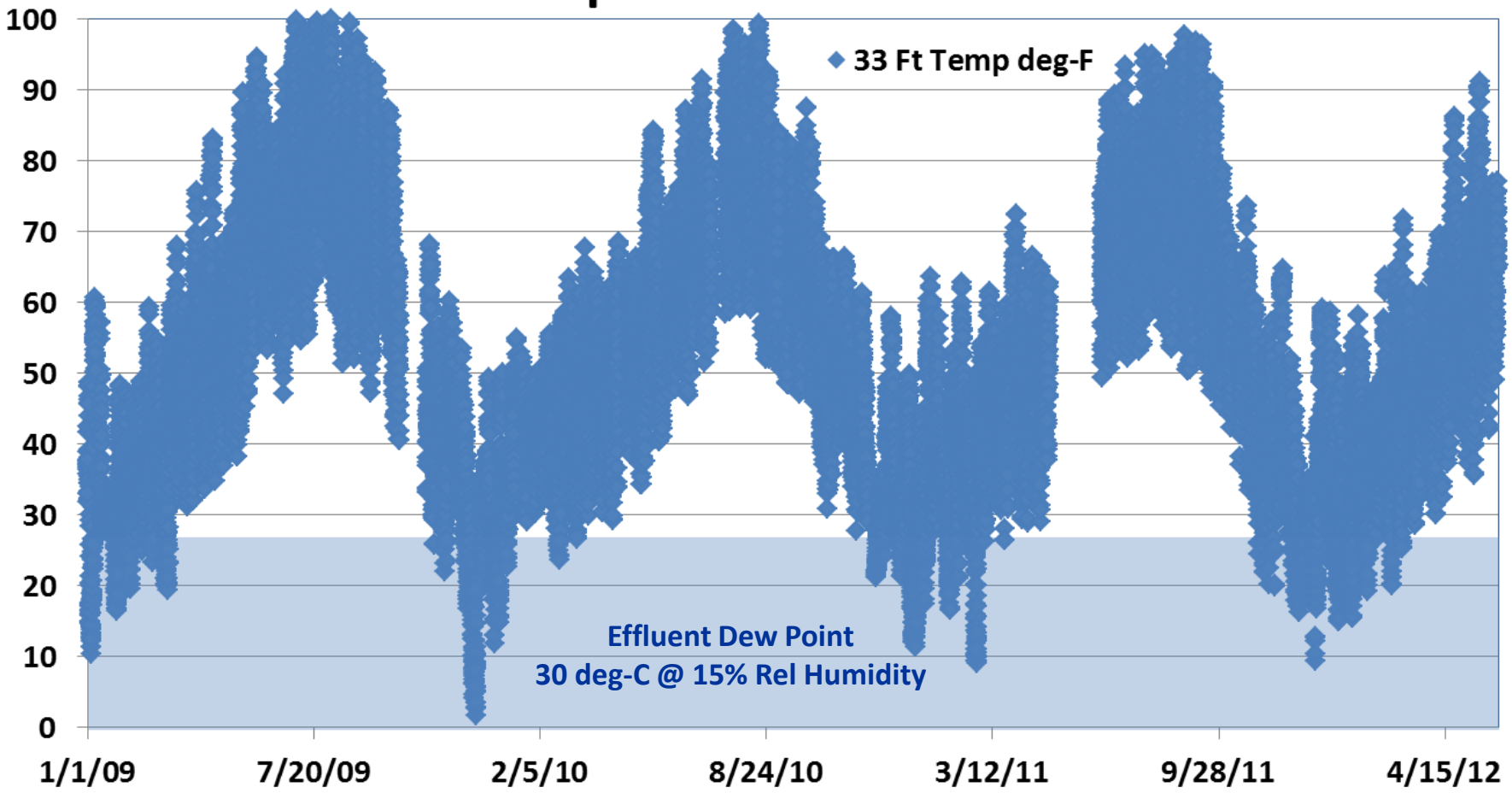
Key Solutions

33 Ft Temps and Effluent Dew Point



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Spray Pond and Cooling Tower Drift

- Fraction of Water Injected into the Atmosphere By Cooling Towers is Still in Liquid Form … Drift
- Larger Droplets in Drift Cloud than in Condensed Water Vapor
  - Less efficient scavenging
  - But Heavier and Deposits More Quickly on Nearby Surfaces

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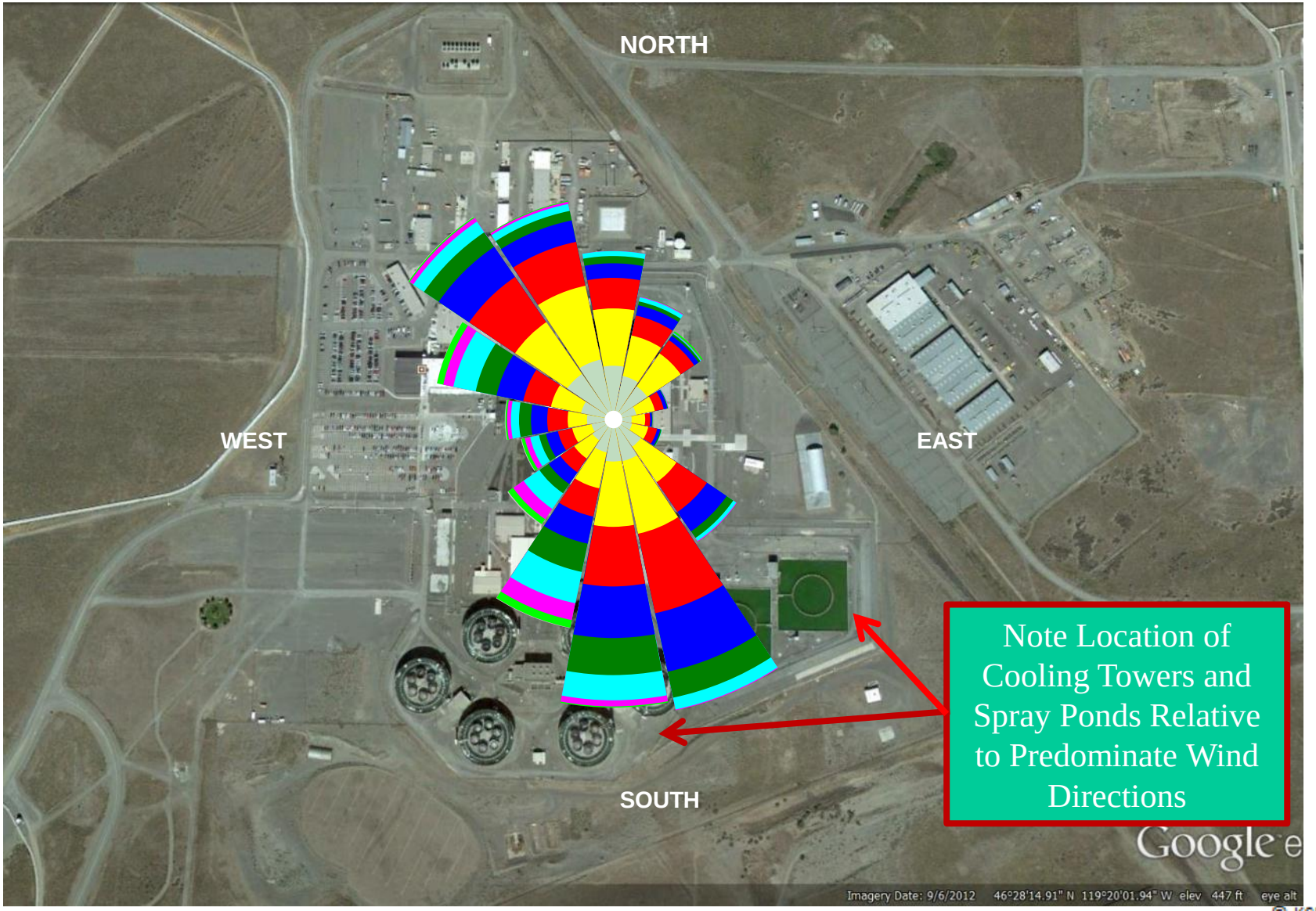
33 Ft Wind Rose - Overlay of Site



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Atmospheric Recapture

- Precipitation Scavenging Rare Event
- Most Significant Recapture Mechanisms:
  - Cooling Pond Drift
  - Cooling Tower Drift
  - Re-Condensation of Cooling Tower and Effluent Plume

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Liquid Rad Waste from Condenser Replacement

- Condenser Water Found To Contain:
  - Ag-110m, Co-58, Co-60, Cr-51, Cs-137, H-3, Mn-54, Sb-124, Zn-65
  - Shipped as Liquid Rad Waste
- Postulated Scenario
  - Some amount of water released to storm drains.
  - Some nuclides in condenser water are were also found in SDP (Co-58, Co-60, Cs-137, Zn-65)

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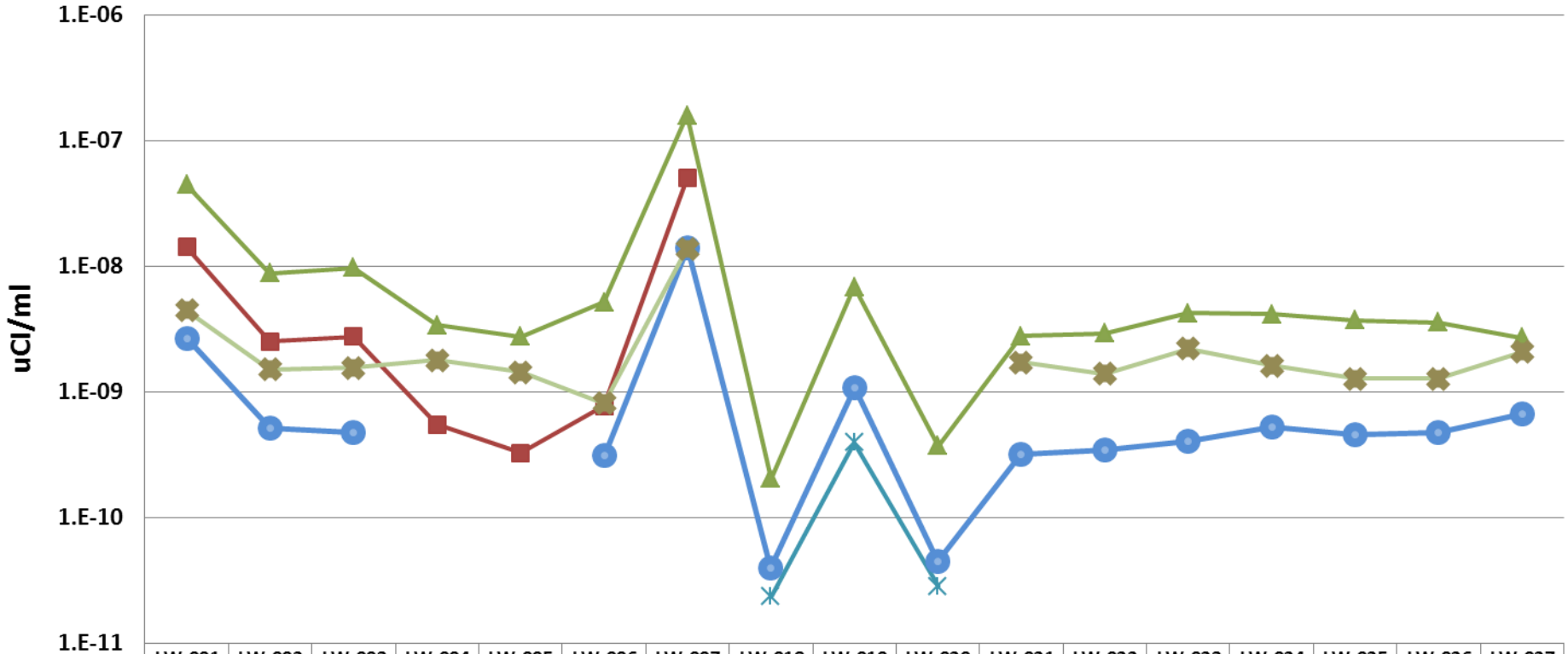
Key Solutions

Nuclides Common to SDP and Condenser Water Shipment of 9/20/11



	LW-001	LW-002	LW-003	LW-004	LW-005	LW-006	LW-007	LW-018	LW-019	LW-020	LW-021	LW-022	LW-023	LW-024	LW-025	LW-026	LW-027
Co-58	1.43E-08	2.53E-09	2.77E-09	5.47E-10	3.26E-10	7.73E-10	5.05E-08										
Co-60	4.46E-08	8.78E-09	9.77E-09	3.39E-09	2.75E-09	5.17E-09	1.60E-07	2.03E-10	6.84E-09	3.71E-10	2.78E-09	2.94E-09	4.26E-09	4.16E-09	3.73E-09	3.58E-09	2.71E-09
Cs-137								2.33E-11	3.93E-10	2.84E-11							
Mn-54	2.68E-09	5.10E-10	4.71E-10			3.10E-10	1.42E-08	3.93E-11	1.08E-09	4.45E-11	3.17E-10	3.42E-10	4.04E-10	5.21E-10	4.56E-10	4.75E-10	6.65E-10
Zn-65	4.45E-09	1.51E-09	1.56E-09	1.79E-09	1.44E-09	8.10E-10	1.39E-08				1.73E-09	1.39E-09	2.22E-09	1.62E-09	1.28E-09	1.28E-09	2.08E-09

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Gaseous Effluents Common to SDP and Condenser Water

	Reactor Building				Turbine Building				Radwaste Building				
Nuclide	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Totals**
Co-58		**5.9E-06**	**1.6E-05**										**2.2E-05**
Co-60	**4.7E-06**	**3.7E-05**	**1.4E-04**	**3.1E-06**	**5.6E-05**	**5.6E-06**	**8.5E-06**	**6.6E-06**	**9.0E-07**				**2.7E-04**
Cs-134													
Cs-137													
Mn-54		**9.2E-06**	**2.3E-05**										**3.2E-05**
Zn-65	**3.6E-06**	**2.1E-05**	**5.2E-05**		**3.7E-04**	**2.4E-05**			**8.0E-07**				**4.7E-04**
Fe-59			**8.7E-06**										**8.7E-06**
Zr-95													

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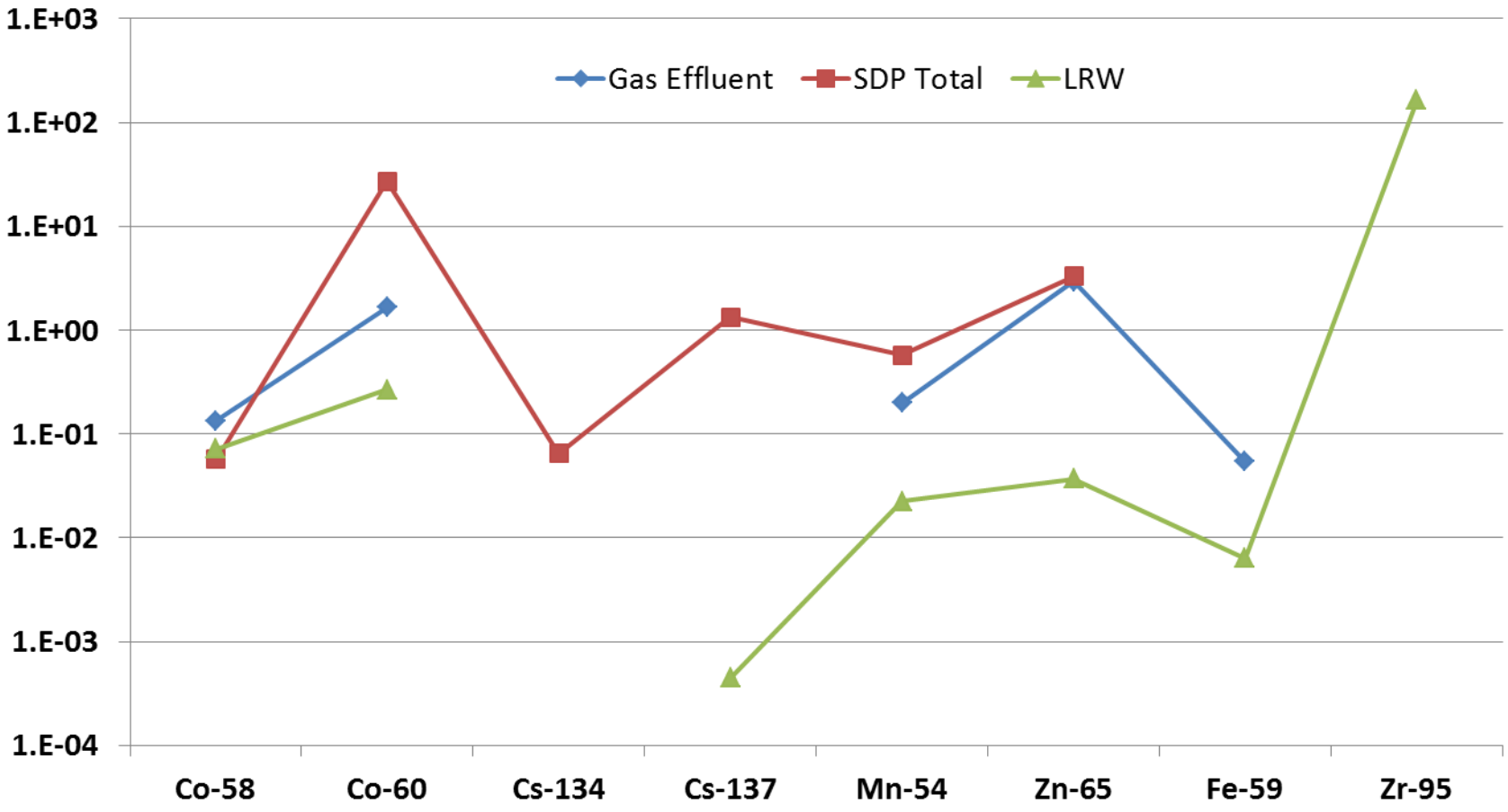
Comparison of Relative Concentrations



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Condenser Water Release?

- Concentration of Zr-95 in Condenser Water ~ 4 Orders of Magnitude Greater Than Zn-65
- Zn-65 Detected in SDP – But Not Zr-95
  - If Deposition Took Place in a Short Period of Time (i.e. the Condenser Water Being Released into Storm Drains) Would Expect to Have Easily Seen Zr-95.
- Not Likely Scenario

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Rain Washout or Recapture?

- Nuclides in Common With Gaseous Effluent Releases and SDP
  - Co-58, Co-60, Mn-54, Zn-65
- Cs-134 and Cs-137 Seen in Storm Drain Pond But Not In Gaseous Effluent Releases

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Cs-134 and Cs-137

- Cs-134
  - Shielded Fission Product – Not part of Fission beta decay chain.
  - Primary Production by Thermal Neutron Activation of Cs-133 or Neutron Capture by Ba-134
  - Rarely Seen in Environmental Samples and Commonly Dismissed as a Misidentification
- Cs-137
  - Ubiquitous and Has Long Persistence in Environment
  - Nutrient Analog to Potassium and Therefore Easily Incorporated into Plants and Animals
  - Has Potential for High Biomagnification Over Time
- Neither Are a Reliable Indicator

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Recapture!

- Recapture Due To:
  - Rain Scavenging (although precipitation events are not common at CGS)
  - Re-Condensation of Effluent and Cooling Tower Plume
    - Routine Periods Where Plume Temperature Can Drop Below Dew Point
  - Drift From Spray Ponds.

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Big Clue!

- Wind Roses Indicate That Substantial a Portion of Time the Plume and Drift from the Cooling Tower and Spray Pond Will Pass Over Plant Atmospheric Release Points.

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Guess Where Reactor Building Is

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Watch Carefully

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Rain/ Monitoring

- Suggest Precipitation Monitoring
- Place Precipitation Collectors in Various Locations
  - Capture Both Rainfall and Drift
- Use Weather Forecast for Timing
- Evaporation is Problem
  - Solution is a Small Amount of Oil in Collector.
  - Prevents Evaporation

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