

# Source Identification of a Continuous Dry Weather Stormwater Collection System Discharge

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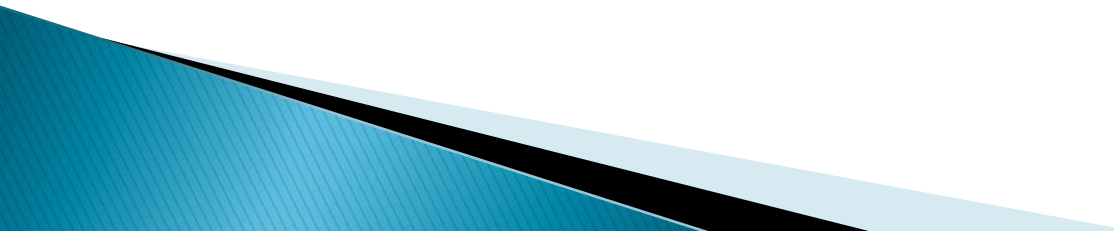
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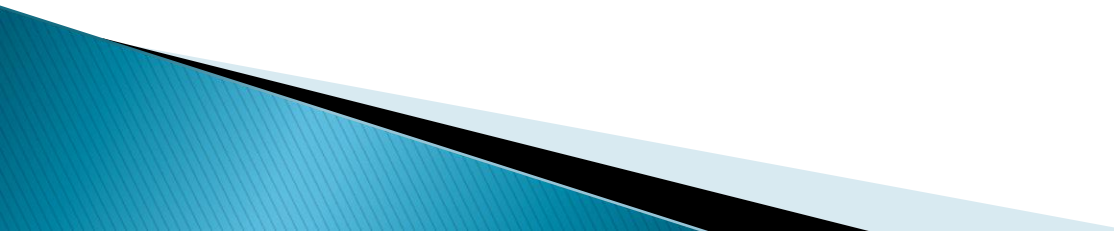
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# Background

- ▶ Malmstrom Air Force Base (MAFB) is located in Great Falls, MT
  - ▶ Significant amount of dry weather flow present in the storm sewer collection system
  - ▶ Continuous flow discharges to Whitmore Ravine eventually reaching the Missouri River
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# Issues

- ▶ The constant high flow of water has caused considerable erosion in Whitmore Ravine
  - ▶ The erosion has led to:
    - Increased deposition in the Missouri River
    - Public protest over damage to private farm land and the adjoining state managed easement
    - Congressional concern over the DoD impact to the watershed
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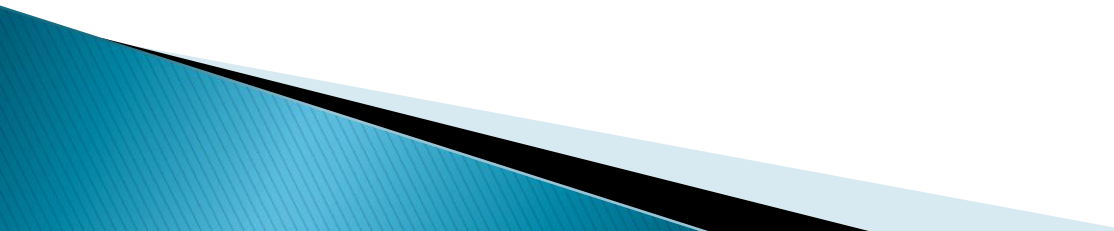




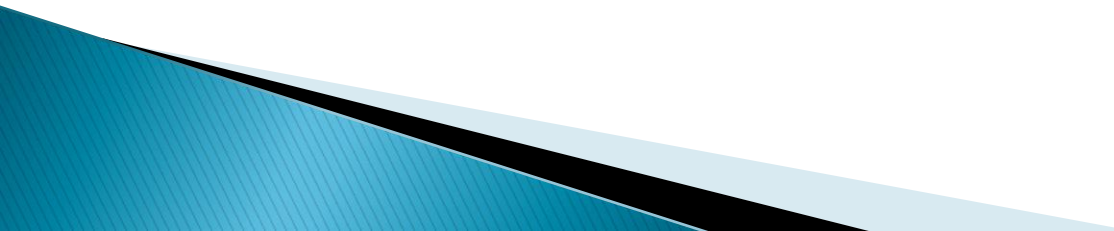




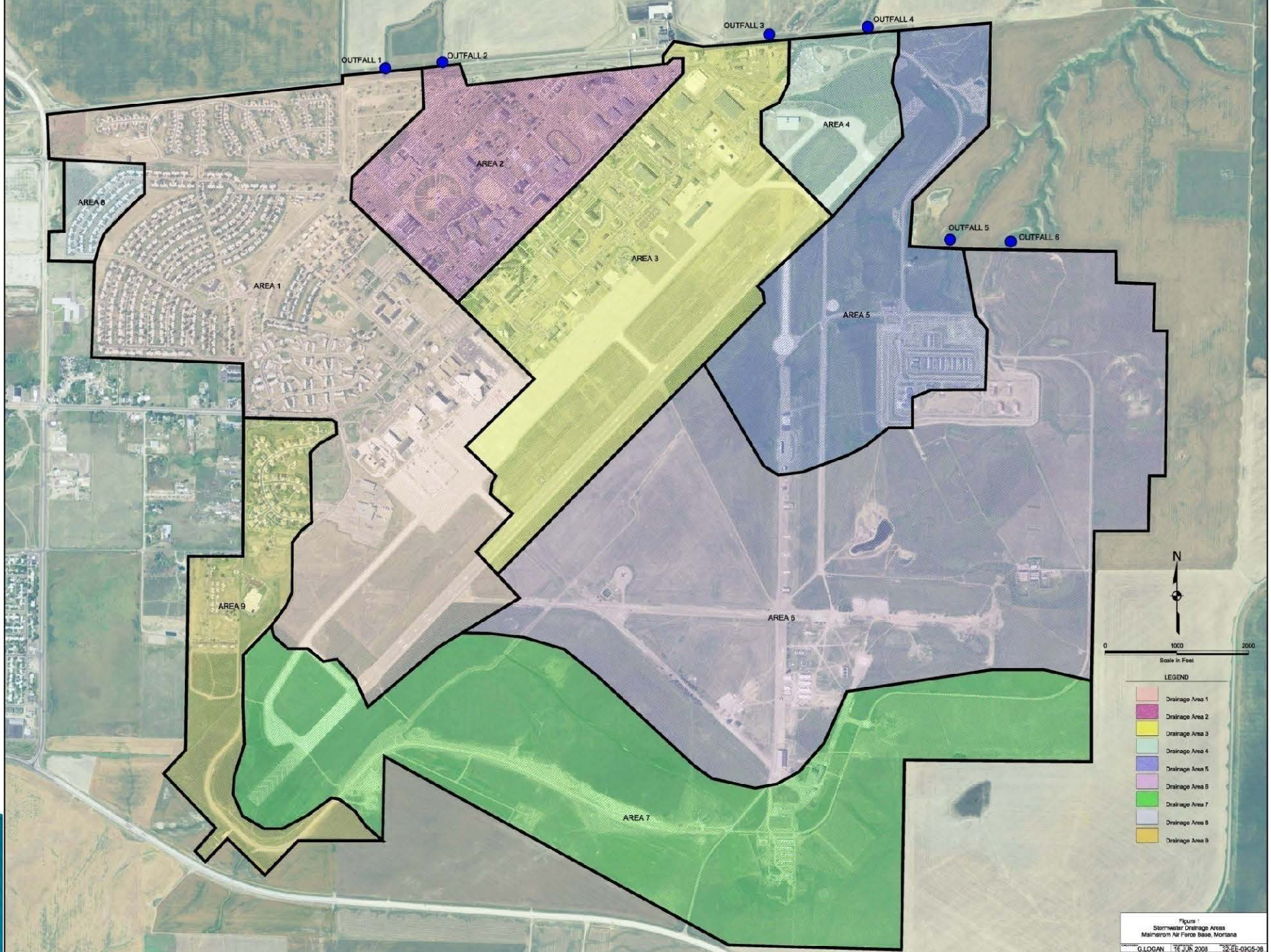
# Project Goals

- ▶ Determine the source(s) of the continuous dry weather flow
  - ▶ Quantify the flow
  - ▶ Evaluate alternatives for managing the flow
- 

# Stormwater Collection System

- ▶ Majority of the system built in the 1950's
  - ▶ Traditional concrete piping throughout the main part of the installation
  - ▶ Flight line constructed using a combination of concrete piping and drain tile
  - ▶ Nine drainage areas on the installation
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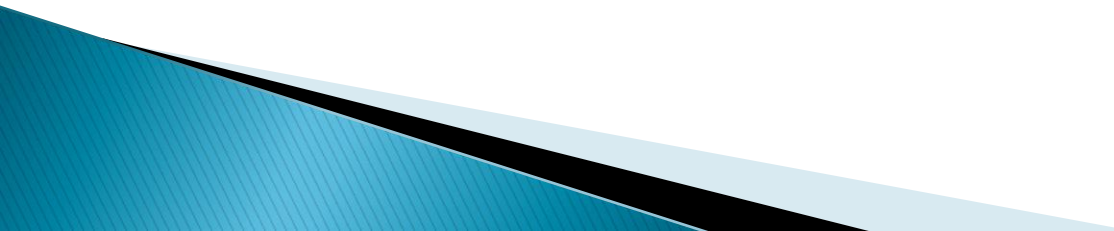


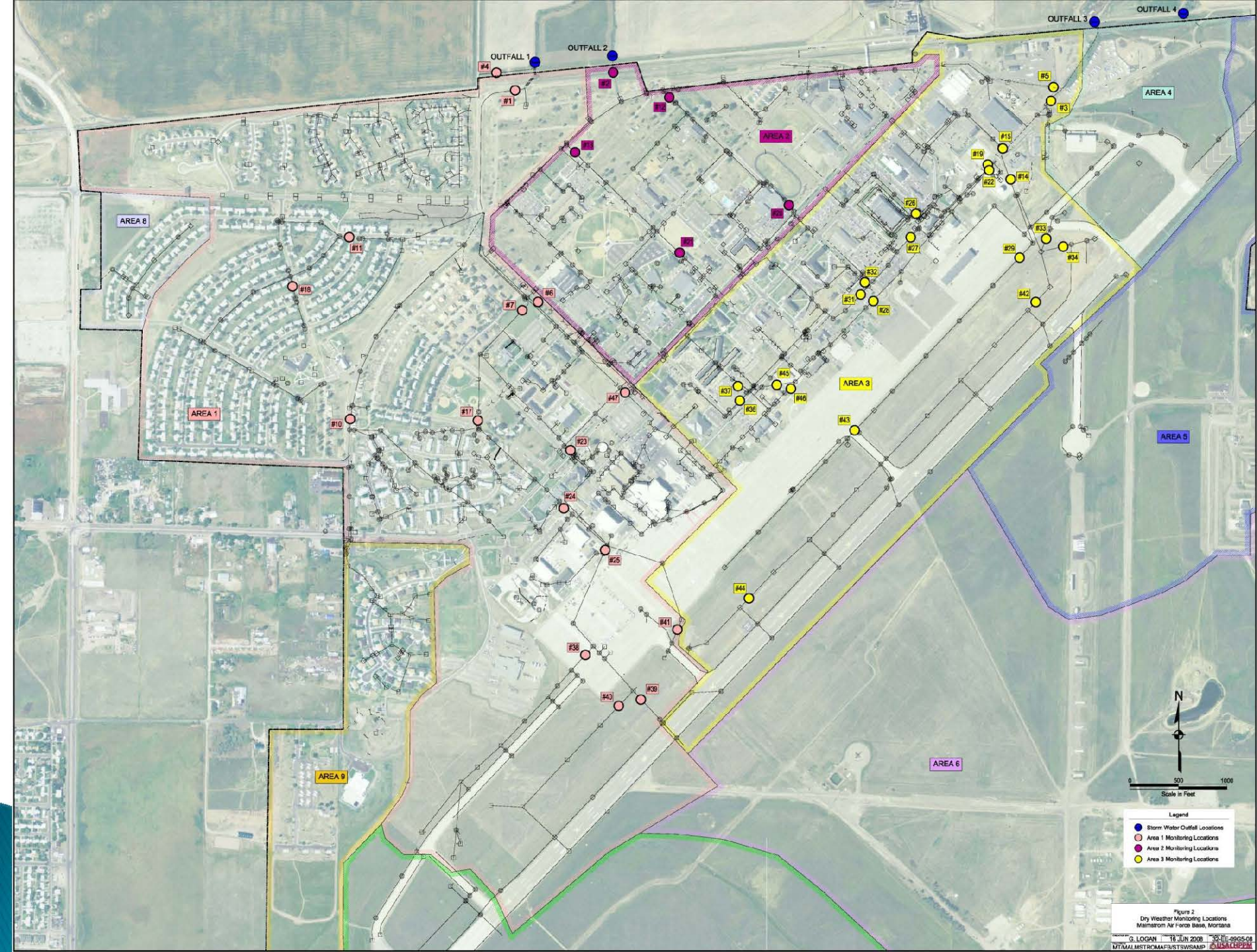


- LEGEND
- Drainage Area 1
  - Drainage Area 2
  - Drainage Area 3
  - Drainage Area 4
  - Drainage Area 5
  - Drainage Area 6
  - Drainage Area 7
  - Drainage Area 8
  - Drainage Area 9



# Approach

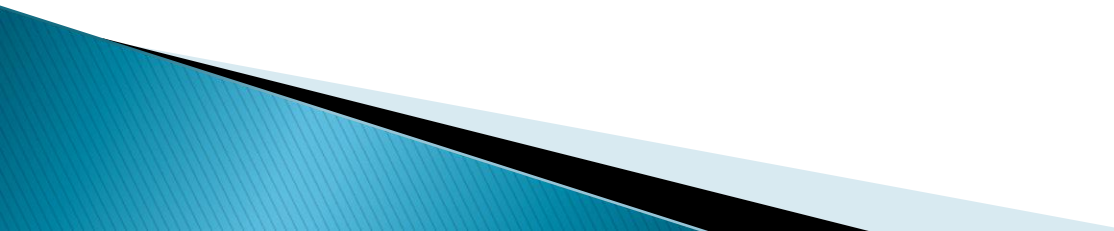
- ▶ In-situ flow analysis at key sections of the MAFB collection system during dry weather
  - ▶ Monitoring points (MPs) were set up at the three outfalls experiencing dry weather flow
  - ▶ The dry weather flow at each outfall was followed upstream and additional MPs were established
- 



- Legend
- Storm Water Outfall Locations
  - Area 1 Monitoring Locations
  - Area 2 Monitoring Locations
  - Area 3 Monitoring Locations

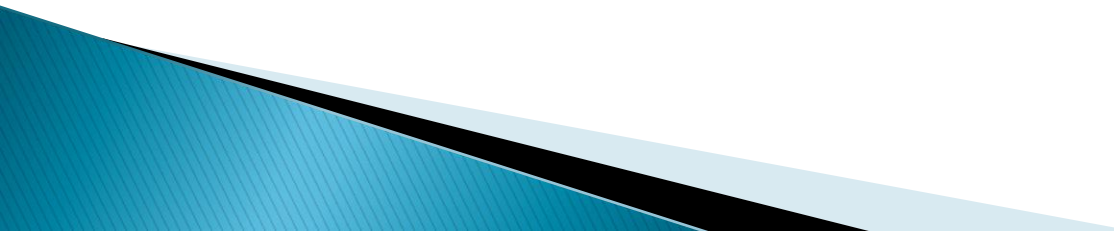


# Whitmore Ravine

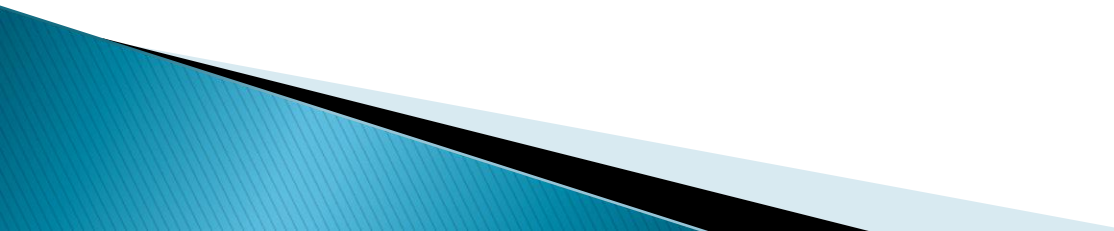
- ▶ MPs were also established in Whitmore Ravine
  - ▶ To determine if any additional flow was contributing to the final discharge at the Missouri River
  - ▶ Continuous monitoring of these discharges was not possible
  - ▶ Instantaneous flow monitoring was performed daily
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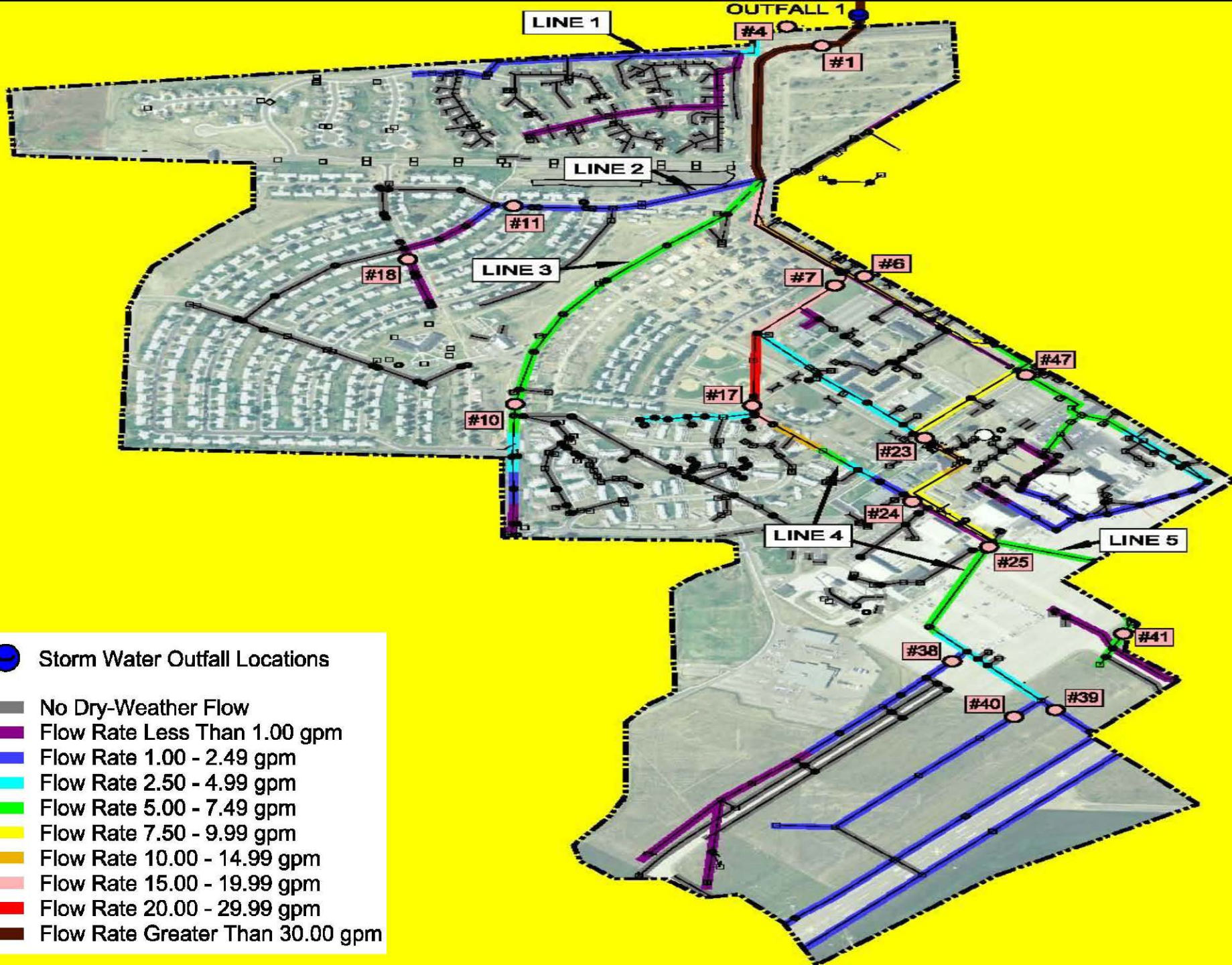


# Analytical Sampling

- ▶ Used to compare dry weather flow with potential water sources to determine origin
  - ▶ Grab samples from potable water and ground water were used for comparison
  - ▶ Conductivity, pH and cation/anion analysis were performed
- 

# Results – Outfall 1

- ▶ Encompasses all housing areas, western portion of base operations and southwestern tip of flight line
  - ▶ Discharge ~ 44 gpm
  - ▶ 51% of total dry weather flow
- 



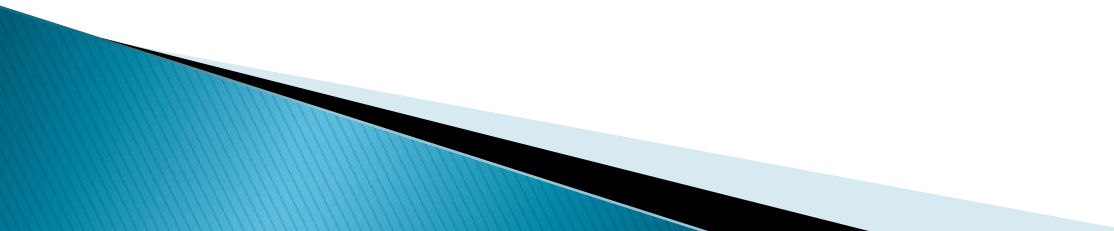


# Groundwater Infiltration

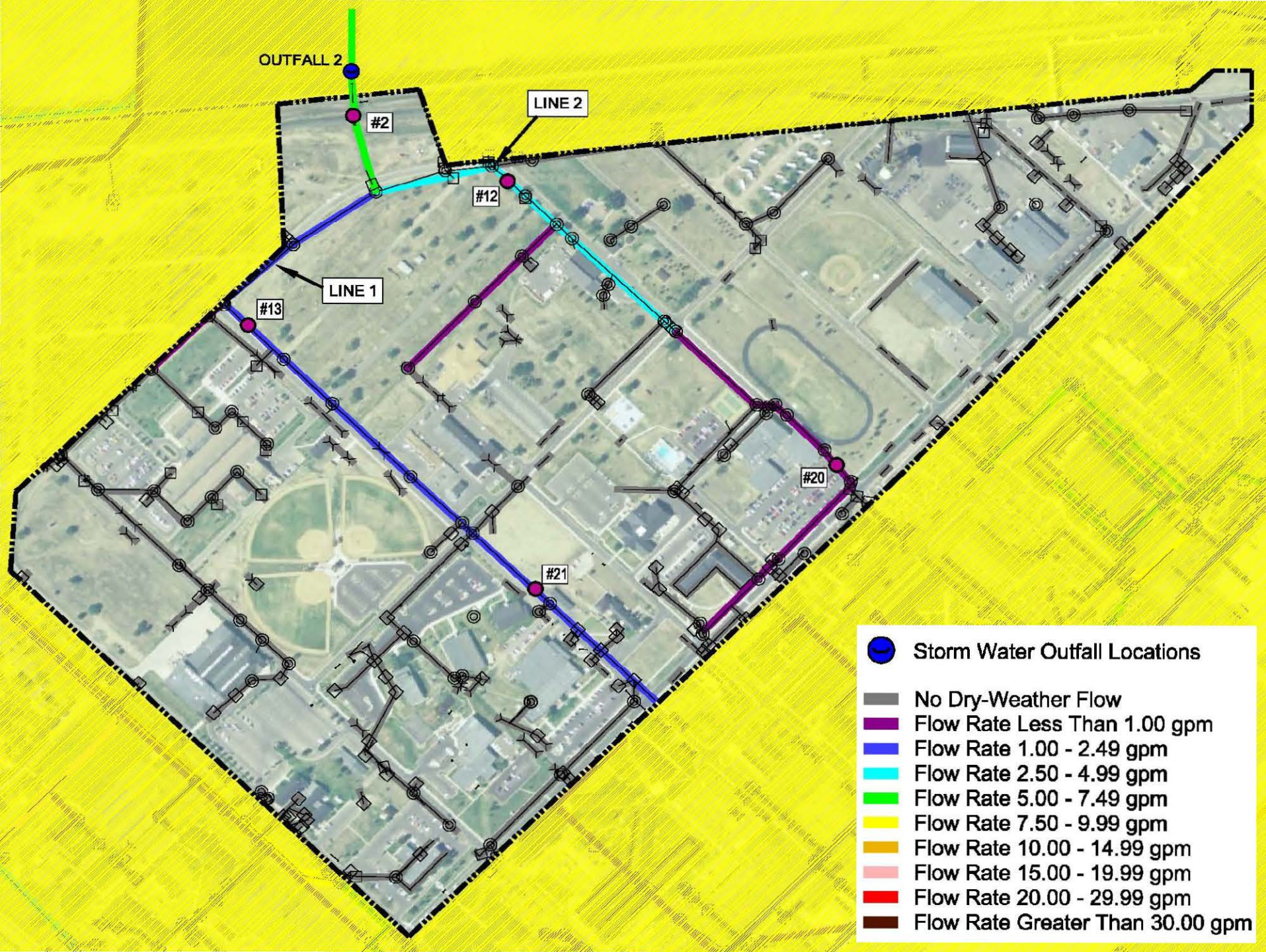




# Results – Outfall 2

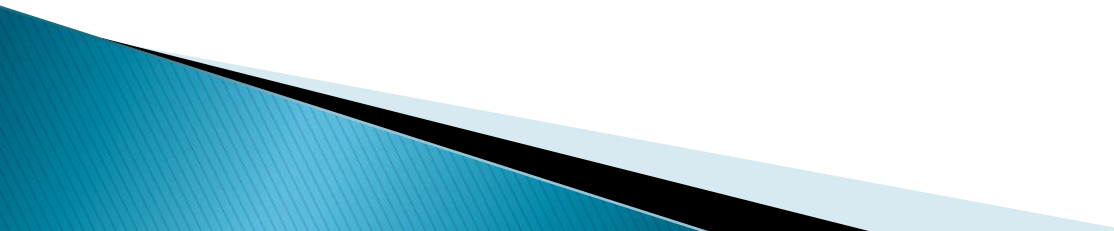
- ▶ Encompasses the central portion of base operations
  - ▶ Discharge ~ 6 gpm
  - ▶ 7% of total dry weather flow
- 

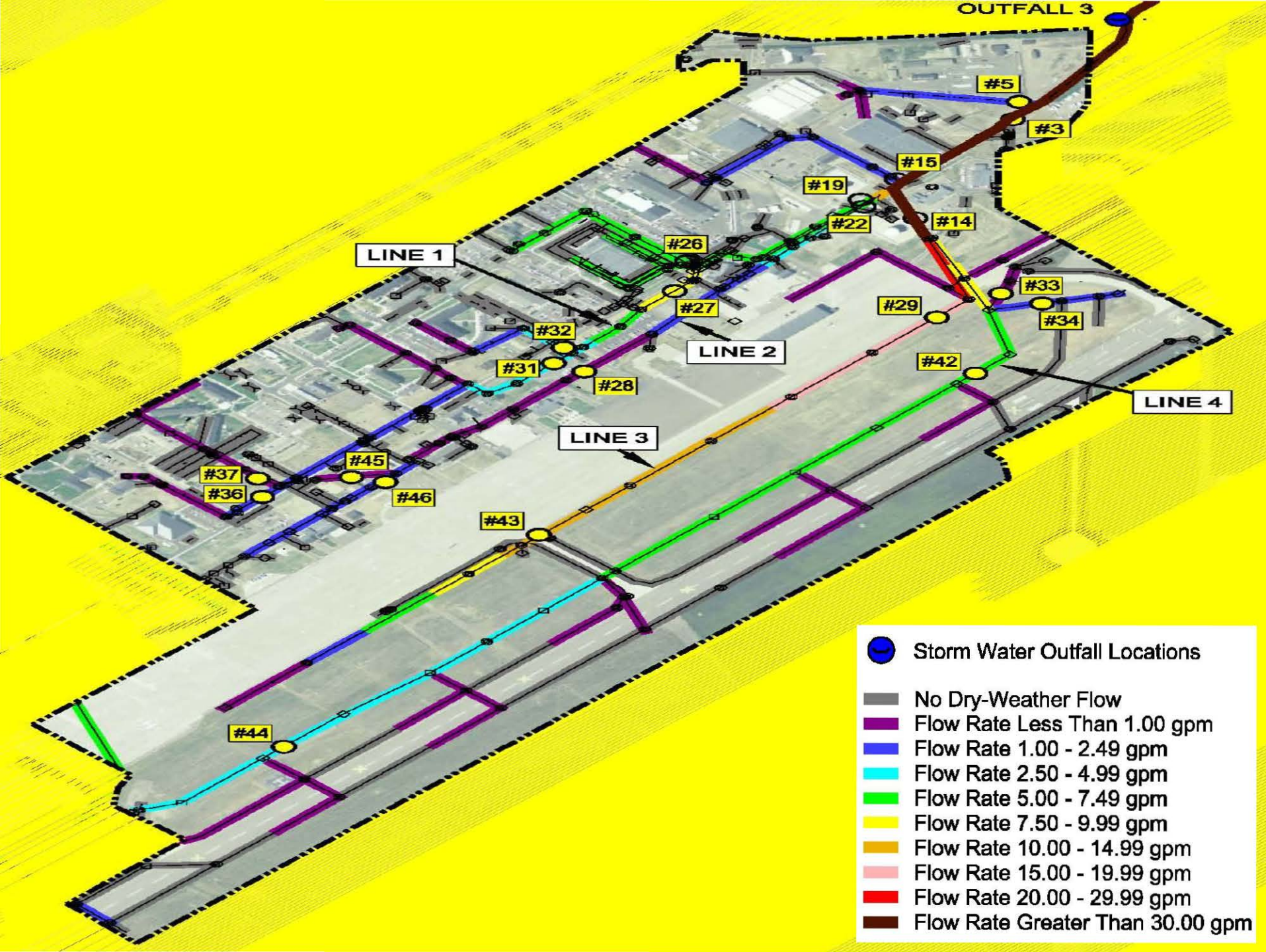




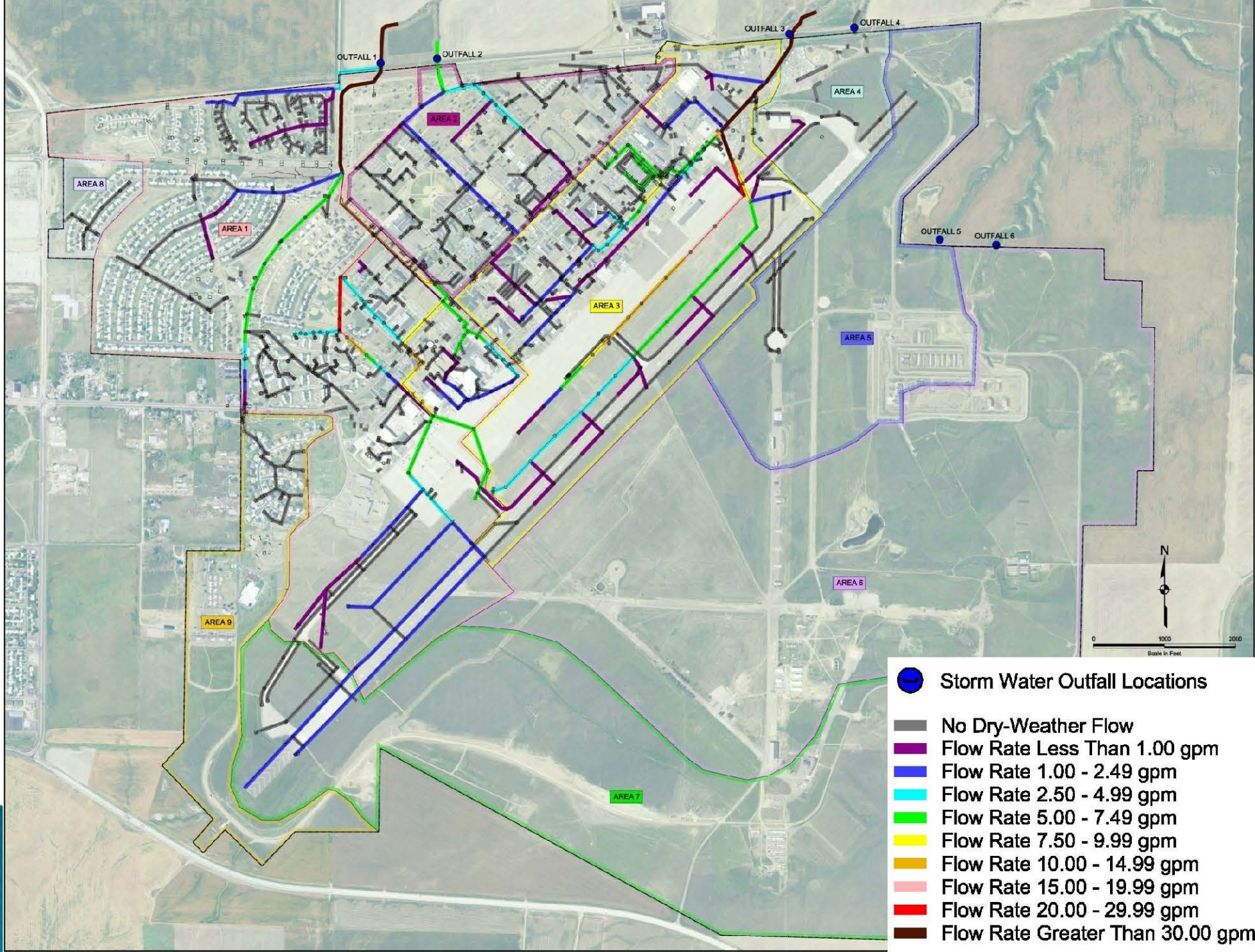


# Results – Outfall 3

- ▶ Encompasses the northeast portion of base operations and almost the entire flight line
  - ▶ Discharge ~ 36 gpm
  - ▶ 42% of the total dry weather flow
- 







# Results – Whitmore Ravine

Date	Flow Rates (gpm)					
	East Fork (MP 8)	Outfall 3	% From MAFB	West and Middle Forks (MP 9)	Outfalls 1 + 2	% From MAFB
16 Apr 08	43.0	27.1	63%	19.9	13.9	70%
17 Apr 08	35.5	27.6	78%	23.3	15.6	67%
15 May 08	57.4	33.9	59%	63.4	54.9	87%
16 May 08	35.5	27.1	76%	35.8	47.9	100%
17 May 08	19.7	25.2	100%	34.8	47.2	100%
18 May 08	26.1	27.6	100%	50.2	39.8	79%
19 May 08	19.7	23.3	100%	41.1	23.9	58%
Average	33.8	27.4	81%	38.4	34.7	90%

# Analytical Results

	Bicarbonate Alkalinity (mg/L as CaCO <sub>3</sub> )	Total Alkalinity (mg/L as CaCO <sub>3</sub> )	Sulfate (mg/L)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)
Dry Weather Flow	300	300	407	60.9	140	79	9.3	66
Potable Water	120	120	57.3	13.8	39	11	3	16
Ground Water	360	360	1460	53.5	390	260	36	290

	pH	Conductivity (mS/cm)	TDS (mg/L)
Dry Weather Flow	6.70	1.34	1000
Potable Water	6.60	0.35	220
Ground Water	6.55	3.71	2620



# Summary

- ▶ Groundwater infiltration seems to be the main cause of the dry weather flow
- ▶ Two points of entry:
  - Joints of manholes collars and around piping
  - Drain tiles around the flight line



# Alternatives Evaluation

- ▶ Reuse of dry weather flow for non potable water users
  - On-site irrigation
  - Vehicle washing
  - Non-contact cooling water
- ▶ Repair/Replacement of Stormwater Collection System
  - Disconnection/Replacement of stormwater lines
  - Lining the stormwater collection system

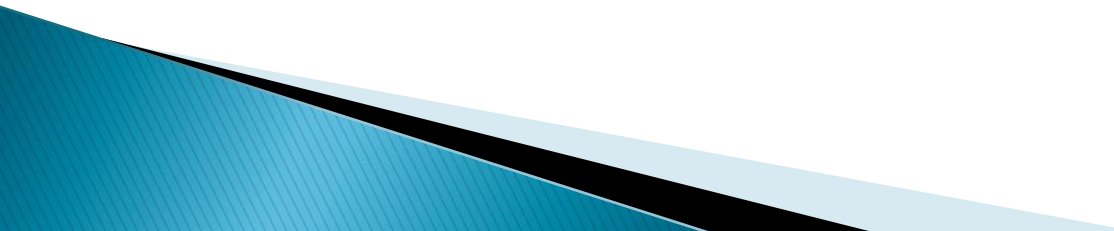
# Alternatives Evaluation Cont'd

## ► On-site irrigation

- Water purchased from City of Great Falls (\$1,630 per MGD)

Month	Total Water Consumption (MGD)	Volume used for Irrigation (MGD)	Cost of Irrigation (\$)
October	15.0	3.0	4,890
November	11.2	0	0
December	13.6	0	0
January	13.1	0	0
February	11.6	0	0
March	10.4	0	0
April	11.8	0	0
May	17.7	5.7	9,291
June	21.1	9.1	14,833
July	43.2	31.2	50,856
August	59.1	47.1	76,773
September	34.5	22.5	36,675
Total	262.3	118.6	193,318

# Alternatives Evaluation Cont'd

- ▶ Reuse for vehicle washing
    - Water management pond would be necessary
    - Construction of a wash rack near the pond
    - Piping to car washes
  
  - ▶ Reuse for non-contact cooling water
    - Central Heat Plant at MAFB is designed to fire natural gas and/or coal
    - Operates October through May
    - When in operation uses ~70 gpm (100 KGal/day)
- 



# Alternatives Evaluation Cont'd

- ▶ Disconnection/Replacement of stormwater lines on the flight line
  - Could significantly decrease dry weather flow to outfalls 1 and 3
  - Would not remove all dry weather flow from collection system
- ▶ Lining stormwater collection system
  - Should reduce groundwater infiltration
  - Expensive

# Conclusions / Recommendations

- ▶ No obvious solution for eliminating flow to Whitmore Ravine
- ▶ Reuse, repair and replacement alternatives will all require significant infrastructure changes and/or additions = expensive
- ▶ Best option for elimination dry weather flow:  
Non potable water reuse
  - On-site irrigation in summer
  - Non-contact cooling water in the winter

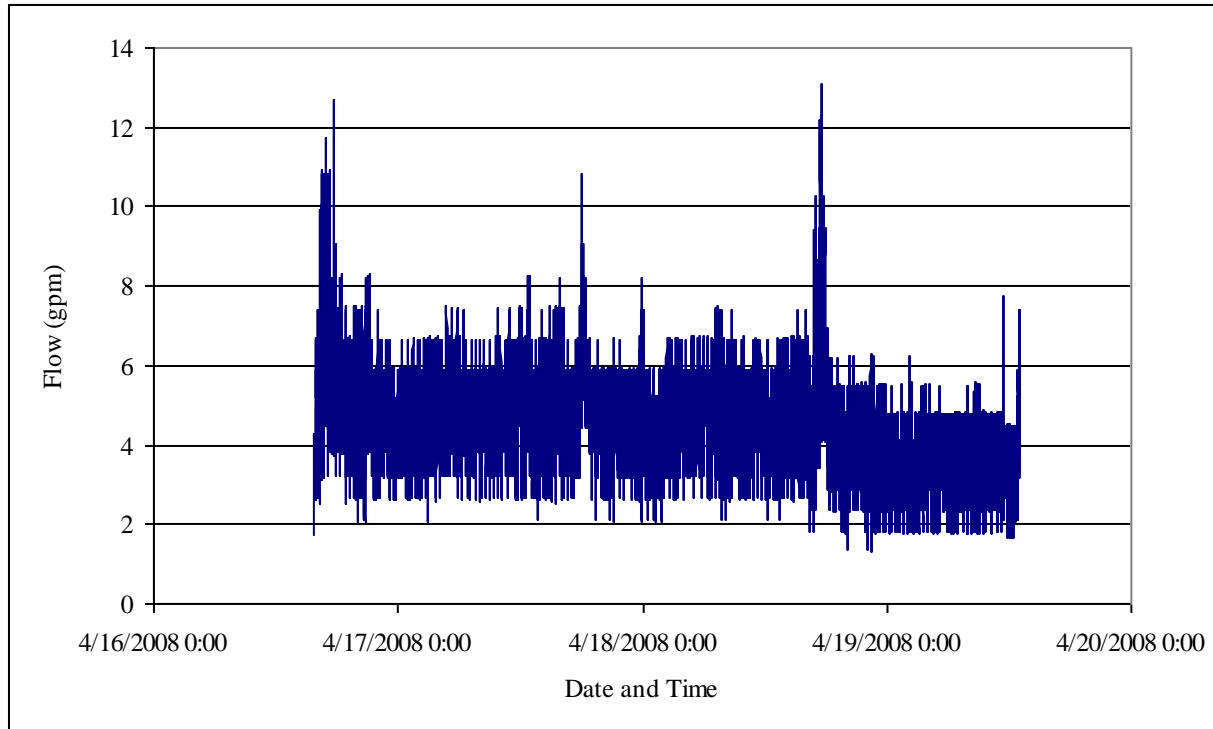


# Questions?



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# Data Example



4/16/2008	34% of the day Total Flow (gal) Average Flow (gpm) Minimum Flow (gpm) Maximum Flow (gpm)	2690.04 5.46 1.73 12.70
4/17/2008	100% of the day Total Flow (gal) Average Flow (gpm) Minimum Flow (gpm) Maximum Flow (gpm)	7096.80 4.93 2.13 10.83
4/18/2008	100% of the day Total Flow (gal) Average Flow (gpm) Minimum Flow (gpm) Maximum Flow (gpm)	6730.20 4.67 1.37 13.09
4/19/2008	50% of the day Total Flow (gal) Average Flow (gpm) Minimum Flow (gpm) Maximum Flow (gpm)	2838.42 3.63 1.64 7.75



# Hydrogeology

- ▶ MAFB sits atop a “bowl” filled with glacial till consisting of clay, sand and silt with gravel
- ▶ Overlying the till is a layer of glacial lake deposit composed of loose, easily erodible sand silt interspersed with clay
  - Can extend from surface to 50 ft deep
  - Contains a underlying layer of clay that may inhibit water from soaking further into the ground
- ▶ Water sits in this “bowl” and can be found very close to the surface