Successful LNAPL Removal Using Air Sparge/ SVE Technology

presented by

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Outline

- Background
- Remedial Options Assessment
- Air Sparging/SVE Technology Evaluation
- Pilot Trial and Biovent Model
- Detailed System Design
- System Operations and Performance
- Conclusions

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Background

- Completed a fast-tracked AS/SVE remediation program in 2004 targeting 30,000L LNAPL plume at a large development site.
- LNAPL product, soil and groundwater contamination extended across 4 lots and beneath a major highway.
- LNAPL originated from a gasoline retail site that operated between 1962-1981.
- Site conditions ideal for AS/SVE application.

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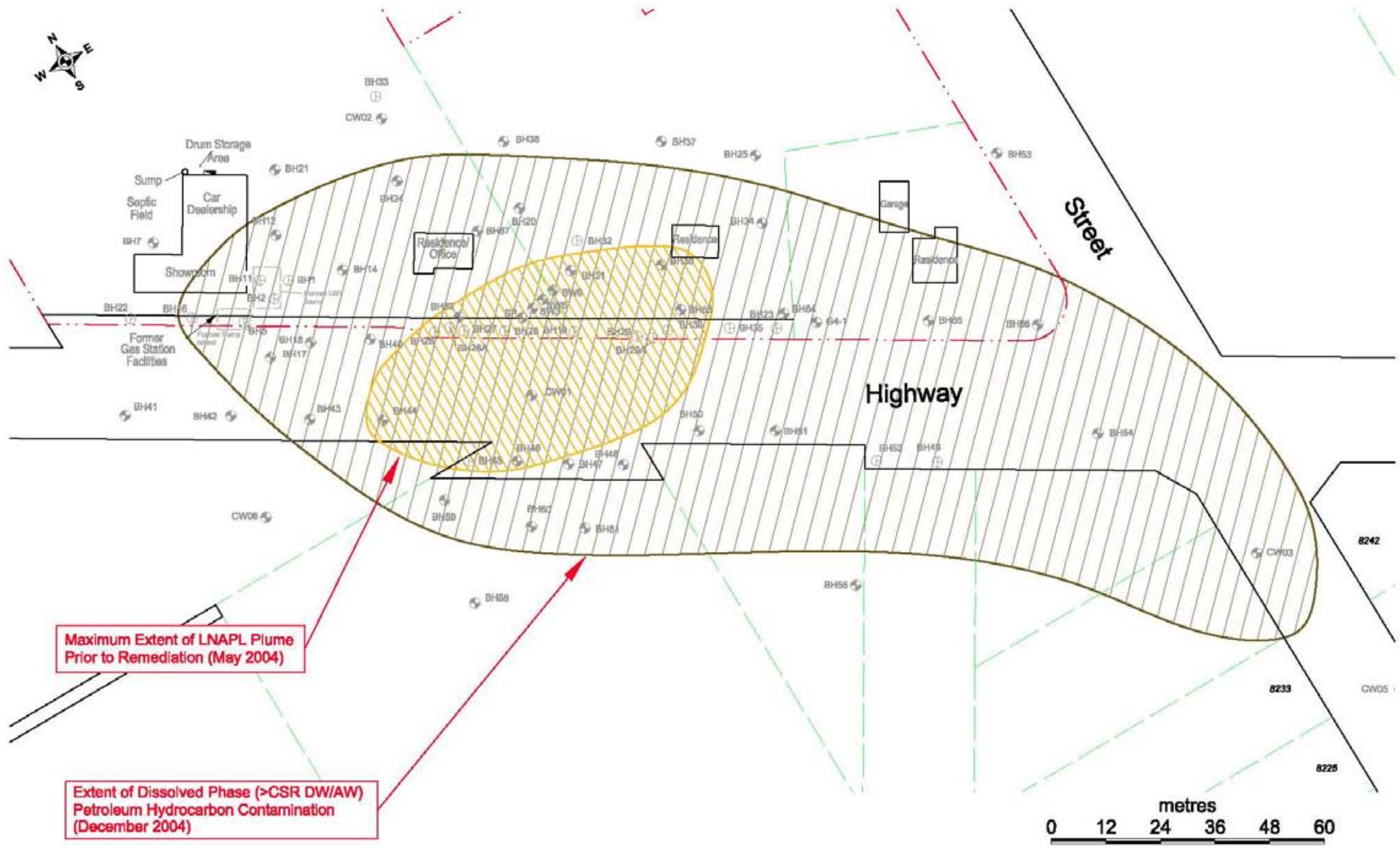

Monitoring Well Location

Destroyed Monitoring Well Location

FIGURE 1

EXTENT OF GROUNDWATER EXCEEDING APPLICABLE CSR STANDARDS

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Remedial Objectives

- Remedial objective was complete LNAPL removal.
- Risk management approach adopted for residual soil and dissolved phase contamination.
- Remedial time-frame critical for multi-site development plans.

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Remedial Options Assessment

- Primary evaluation factor - timeline to completion.
- Cost-benefit analyses secondary to this criterium.
- Ex-situ approaches based on material excavation not practical due to plume extension beneath highway.
- In-situ technologies evaluated with respect to performance capability with site conditions.

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AS/SVE Technology Evaluation

- Technology is 20 years old.
- Design and implementation dependent on empirical knowledge and experience.
- Simple concept but physical, chemical and microbial processes poorly understood.
- AS - injection of air into a contaminated aquifer.
- SVE - vacuum applied to vadose zone to capture vapour phase contaminants leaving saturated zone (different from bioventing).

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AS/SVE Technology Evaluation

- Key factors that limit applicability:
  - Contaminant type and distribution.
    - volatile or semi-volatile?
    - LNAPL present?
  - Geo/hydrogeologic conditions.
    - Site geology permeable or semi-permeable?
    - Site geology homogeneous or heterogeneous?
    - Preferential pathways?
    - Watertable shallow or deep?
    - Confined aquifer?

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AS/SVE Technology Evaluation

- Primary design parameters are soil air permeability and pore volume exchange capacity.
- These factors define the zone of effective air exchange.
- Initial mass transfer rates dictated by partitioning coefficients from sorbed, dissolved and NAPL contaminants.
- Mass transfer rates after long-term operations limited by diffusion kinetics.

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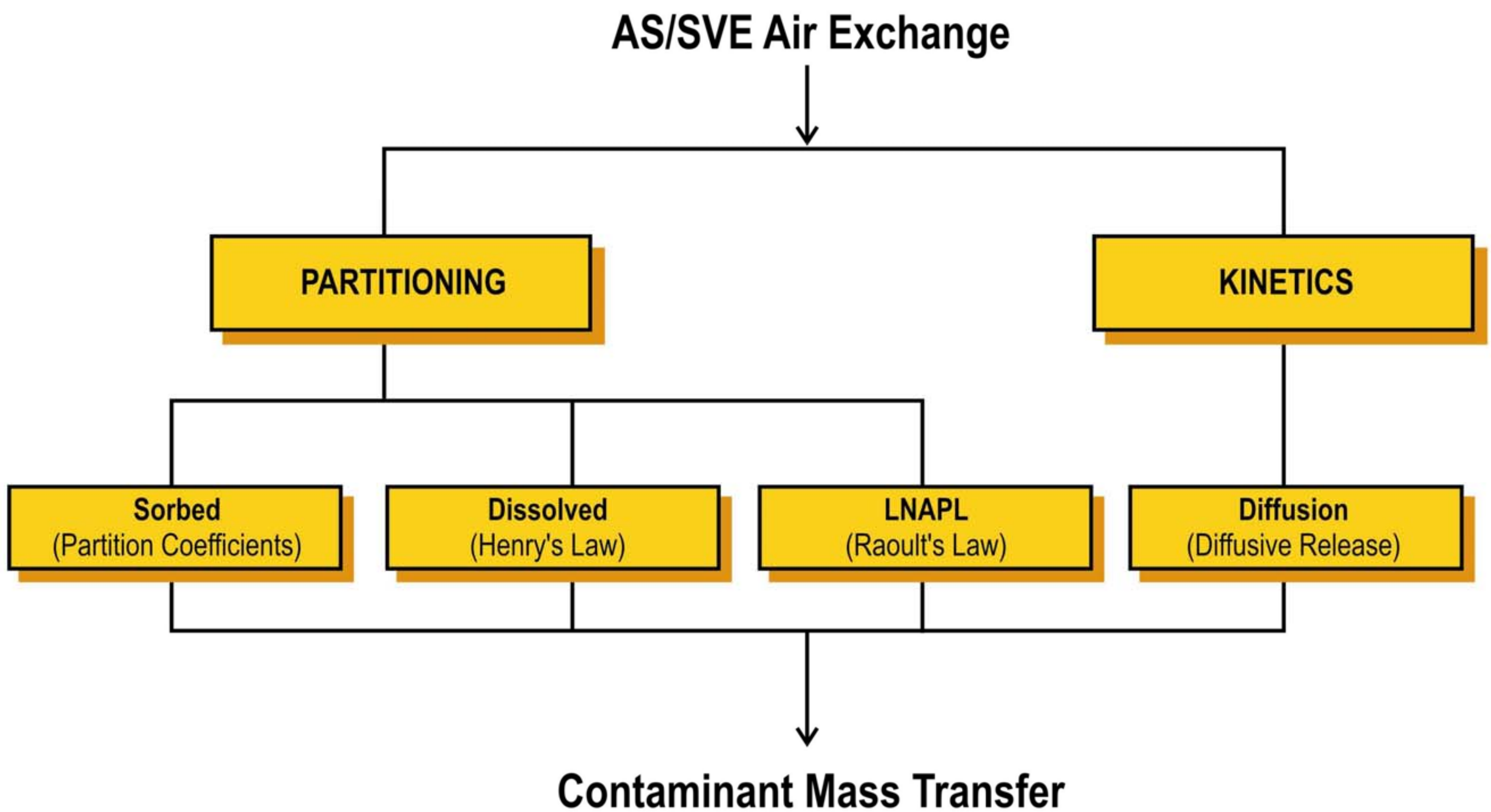
AS/SVE Air Exchange
PARTITIONING
KINETICS
Sorbed
(Partition Coefficients)
Dissolved
(Henry's Law)
LNAPL
(Raoult's Law)
Diffusion
(Diffusive Release)
Contaminant Mass Transfer

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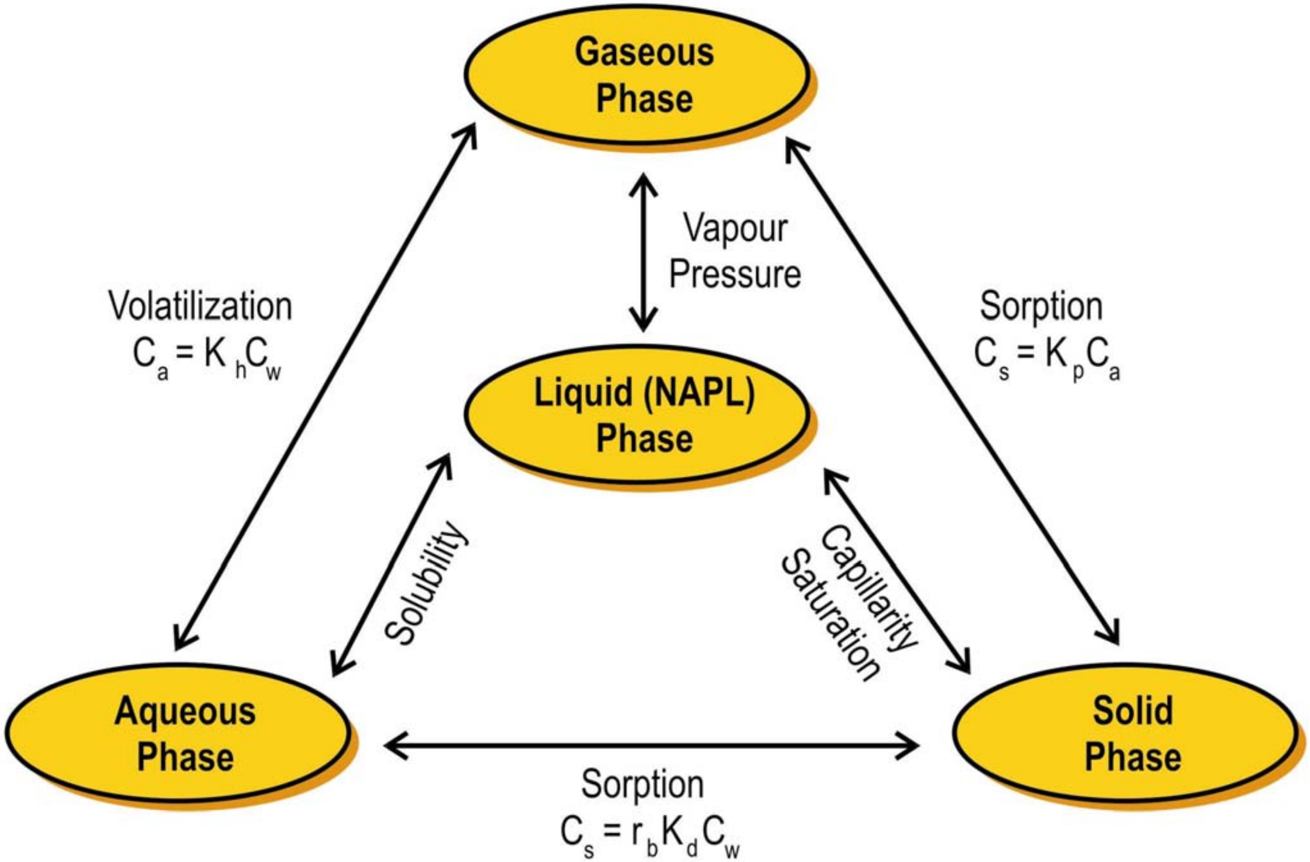

Partitioning of VOCs where:

C_a, C_w, and C_s = concentration of VOC component in air, water and solid;
K_H= Henry's constant;
K_p= partition coefficient;
K_d= distribution coefficient;
and r_b= soil bulk density (USACE, 1995)

AS/SVE Technology Evaluation

- Partitioning relations estimate mass removal rates as a function of time.
- Mass removal rate estimates must account for changes in contaminant composition and behaviour.
- Zone of air exchange should correspond to soil/water/NAPL volume to be remediated.
- Airflow and contaminant mass transfer modeling supports well spacing and layout design.

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AS/SVE Technology Evaluation

- SVE design strategy:
  - To promote contaminant release from soil, water and NAPL.
  - To capture contaminants advectively under an applied vacuum.
- AS design strategy:
  - To promote volatilization of dissolved phase and NAPL contaminants.
  - To enhance water phase biodegredation
  - To increase vadose zone airflow rates.

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AS/SVE Technology Evaluation

- AS/SVE design goal - to balance air exchange rates with contaminant transfer rates from soil/water/NAPL into vapour phases.

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Pilot Trial and Biovent Model

- Single AS and SVE wells tested.
- AS only and varying AS/SVE flowrate combinations trialed over 1 week.
- Pilot trial demonstrated:
  - significant radii of vacuum/pressure and groundwater chemistry influence
  - uniform distribution of air (O_2) to saturated zone
  - peak mass transfer rates when AS and SVE flowrates maximized
  - Groundwater mounding around AS and SVE wells

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Pilot Trial and Biovent Model

- Pilot Trial data used in Biovent Model.
- Uses coupled airflow and contaminant mass transfer models.
- Cost modeling to find balance between capital cost and ongoing O&M costs.
- Cost-benefit model identified an optimal number of 20 sparge points over the NAPL plume area.
- High-density well coverage and increased equipment sizing reduced forecasted remedial timeframe and associated O&M costs.

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Detailed System Design

- Goals of the system design and layout included:
  - To optimize PHC mass transfer rates.
  - To ensure control and management of LNAPL plume.
  - To ensure 100% capture PHC vapours.
- 150 cfm sparge compressor, 500 cfm blower and 500 cfm thermal catalytic oxidizer selected.
- Well network of 20 nested AS/SVE wells and 15 discrete SVE wells installed.
- Controlled in groups via automated valves or individually using well-dedicated valves.


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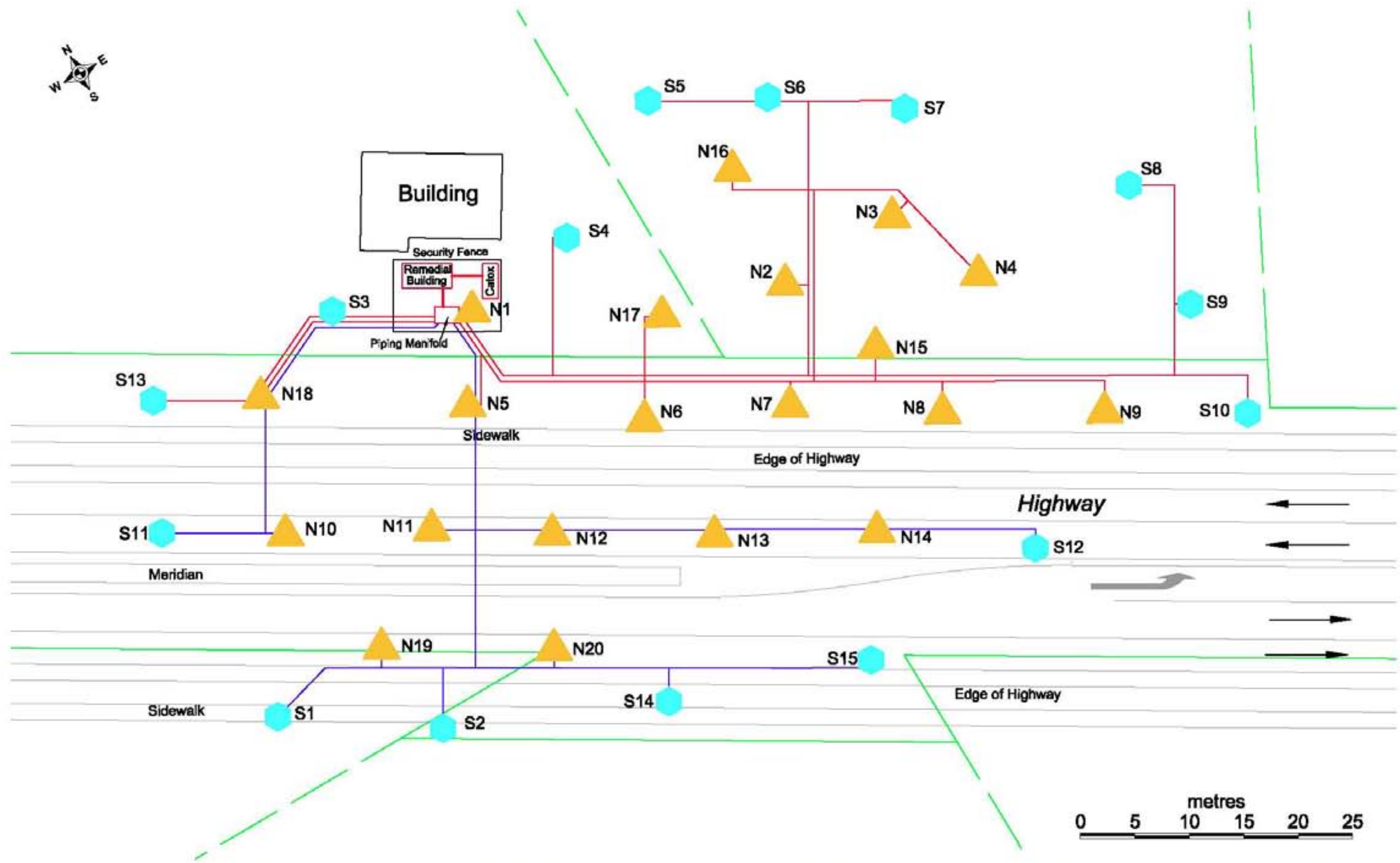

SVE Piping Network (Trench contains 6", 4" and 2" PVC Sch. 40 pipe)

2" Pipe Corridor (dedicated lines)

Inner Control Point Nested Sparge/SVE Well Location

Outer Control Point SVE Well Location

FIGURE 2

SVE PIPING NETWORK

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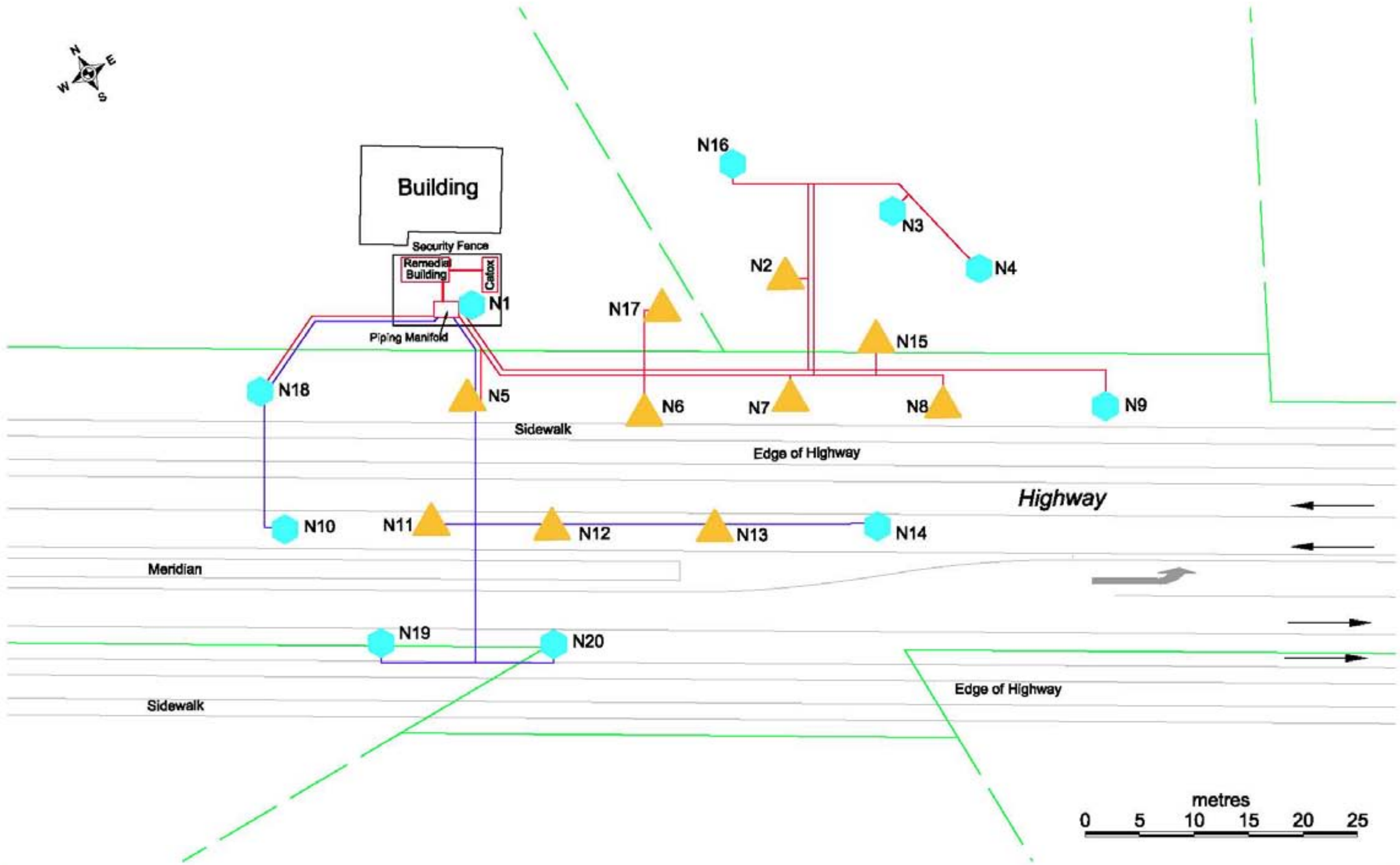

SVE Piping Network
(Trench contains 6", 4" and 2" PVC Sch. 40 pipe)

2" Pipe Corridor (dedicated lines)

Inner Control Point
Nested Sparge/SVE
Well Location

Outer Control Point
Nested Sparge/SVE
Well Location

FIGURE 3

AIR SPARGE PIPING NETWORK

Detailed System Design

- Practical design considerations:
  - AS/SVE wells as nested installations.
  - PVC pipe not rated for compressed air.
  - Manifolds centralized performance monitoring and system control.
  - Fuel consumption lowered by thermal catalytic oxidizer equipped with heat exchanger.

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System Operations and Performance

- System and site monitoring conducted on minimum bi-weekly basis.
- 3 primary stages or modes of operation.
- First – phased addition of 35 SVE wells over first month, average PHC recovery rate = 185L/day
- Second – AS brought online, pulsed operation, average PHC recovery rate 200-300 L/day
- Third – High airflow operation of select AS/SVE wells targeting isolated LNAPL pocket

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System Operations and Performance

- Each stage of operation posed a new challenge.
- First – vacuum unit undersized, groundwater entrainment in SVE only wells.
- Second – system shutdowns due to PHC vapour concentration spikes.
- Third – predicting and controlling LNAPL movement during the final project stages.
- Monitoring and system performance data evaluation critical to remedial effectiveness.

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Conclusions

- 40,000L LNAPL product removed.
- Post-remediation drilling and monitoring demonstrated no rebound occurred.
- Remedial objective met in 9 months.
- AS/SVE technology is a high-impact approach to LNAPL removal.
- Over-design and aggressive operation resulted in a short remedial timeframe and lower project costs.

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Acknowledgements

Chevron

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