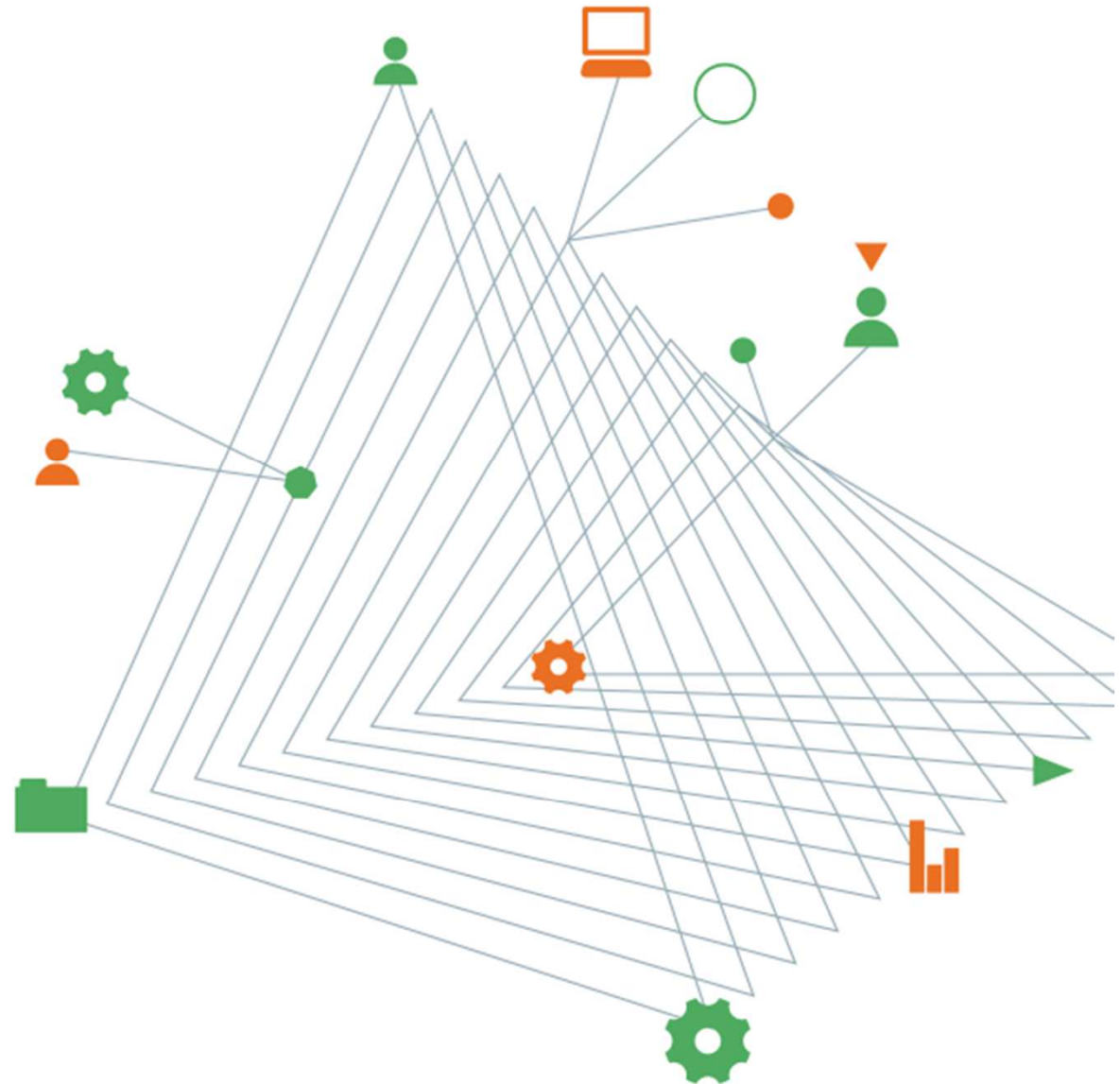


Experience  
comes to life  
when it is  
powered by  
expertise



## The Ballina Bypass

**Richard Kelly**

Senior Principal, Coffey  
Visiting industry fellow, CGSE

AGS Symposium  
Perth 2014

# The Ballina Bypass

12 km of high standard dual carriageway

12 km of local roads

20 major structures

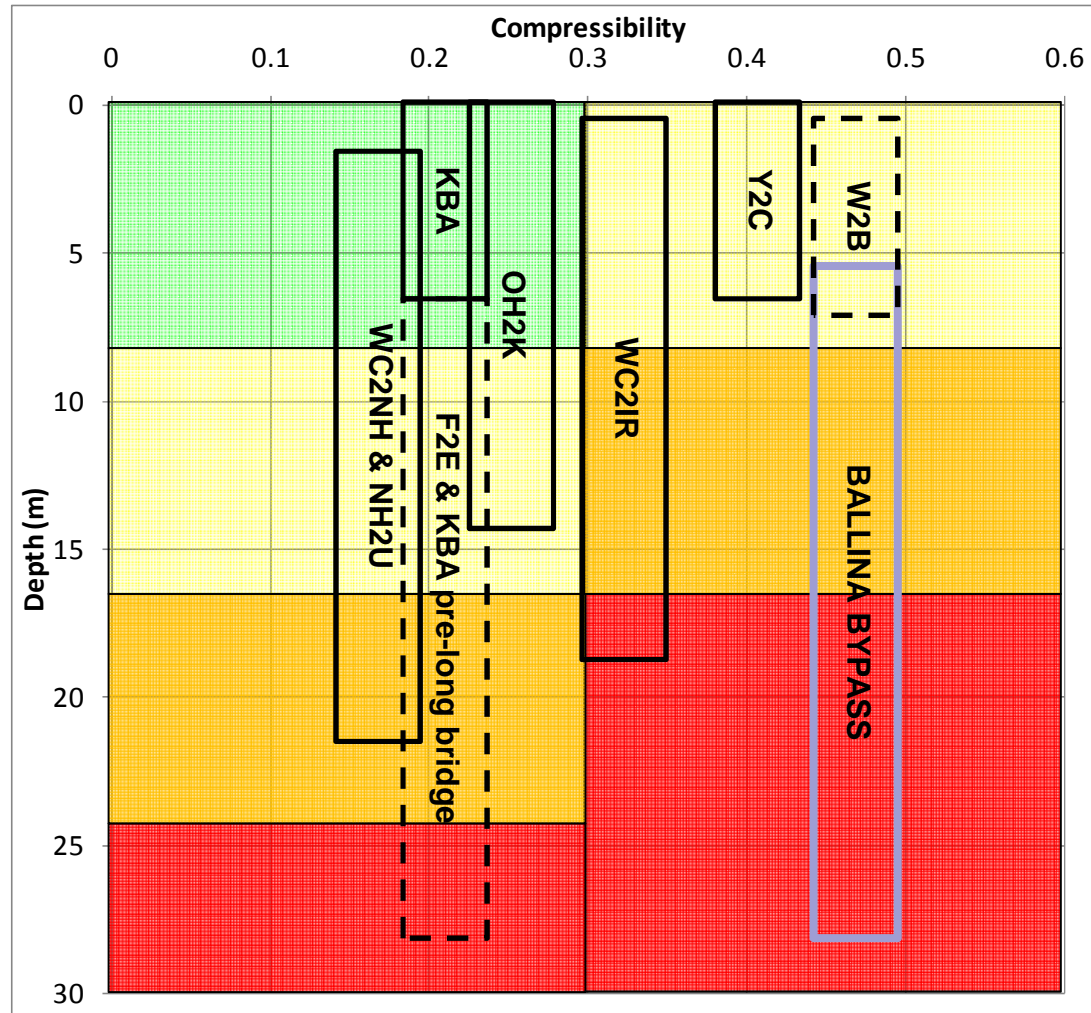
- Bridges
- Arch structures
- Box culverts

Eliminate 2 road safety black spots

Reduce travel times (particularly in holiday periods)



# CHALLENGES: Softest and deepest soils on Pacific Highway



# History of the Ballina Bypass



- Concept design said construction would take 13 years due to staged construction using SWD
- Ground improvement solutions more than halved construction timetable to 2 years of early works and 4 years of construction
- Opened 6 months early and on budget



# CHALLENGES - STABILITY



# CHALLENGES – POST CONSTRUCTION SETTLEMENT

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# CHALLENGES - TRAFFICABILITY



# CHALLENGES – HILLSIDE STABILITY

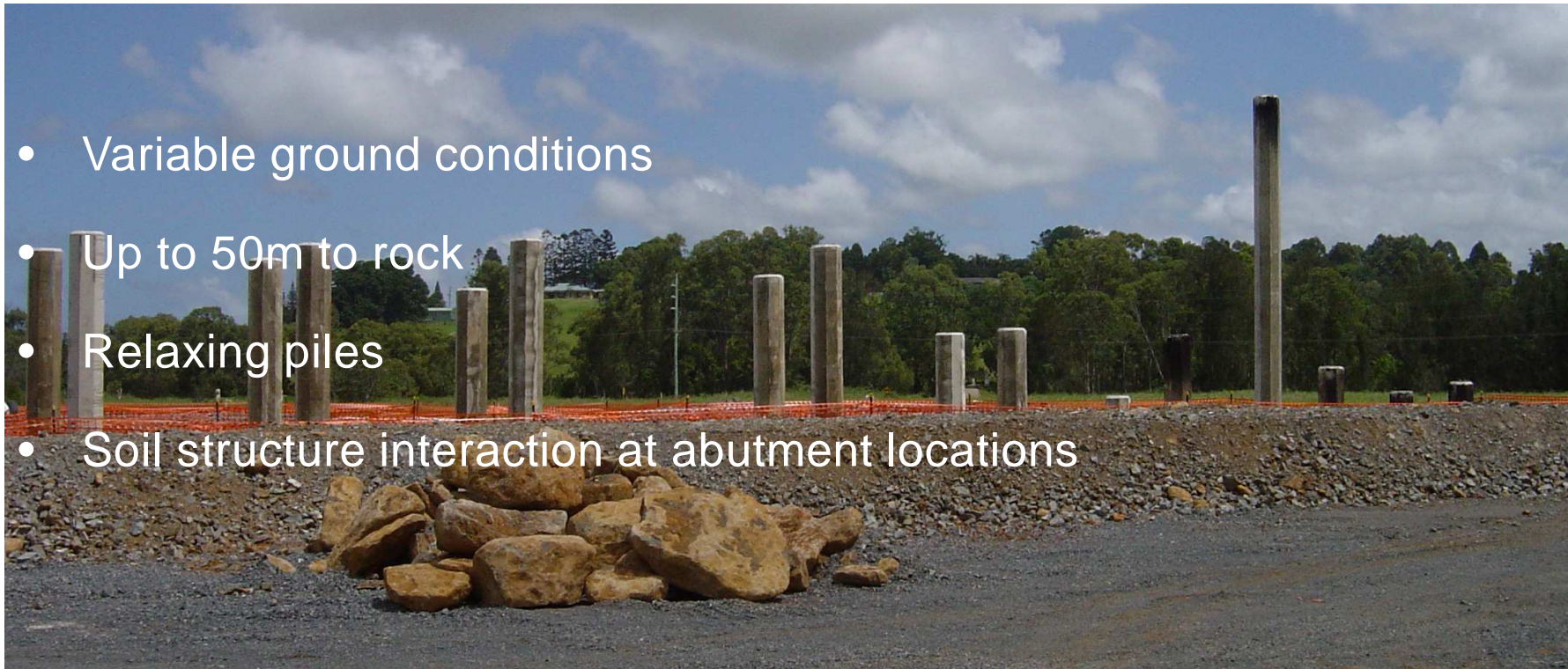


# CHALLENGES – BOULDERS IN FILL



# CHALLENGES - PILING

- Variable ground conditions
- Up to 50m to rock
- Relaxing piles
- Soil structure interaction at abutment locations



# CHALLENGES – TEMPORARY WORKS

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Stability

Sheet piles and geosynthetics

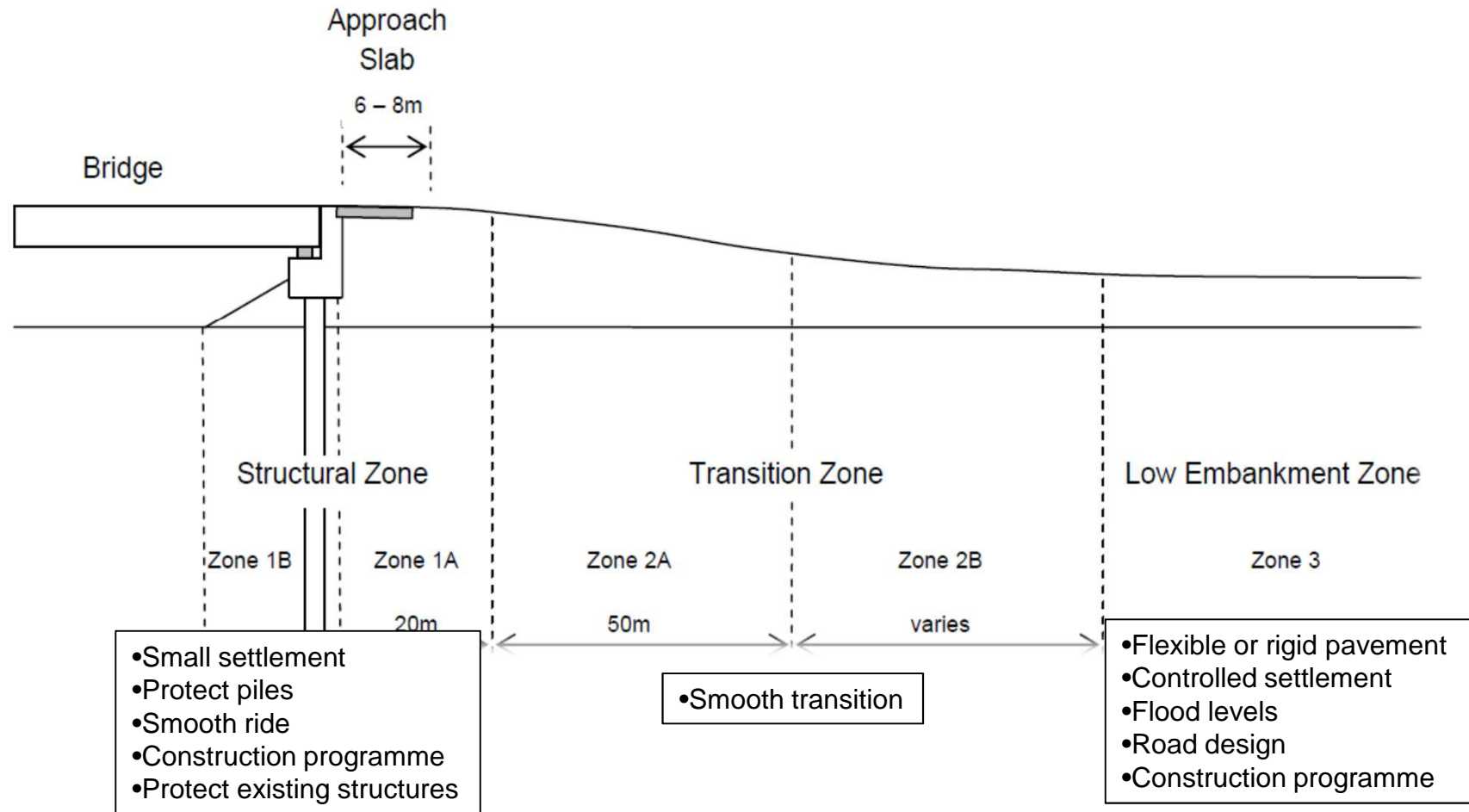
Pile supported platforms

~\$1M per bridge abutment

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- Continuity of bridge construction
  - Managing uncertain settlement periods to meet milestones
  - Minimum settlement periods required for Low Embankment Strategy
-

# AIMS OF EMBANKMENT DESIGN



# SOLUTIONS: Varied and extensive soft soil ground treatments

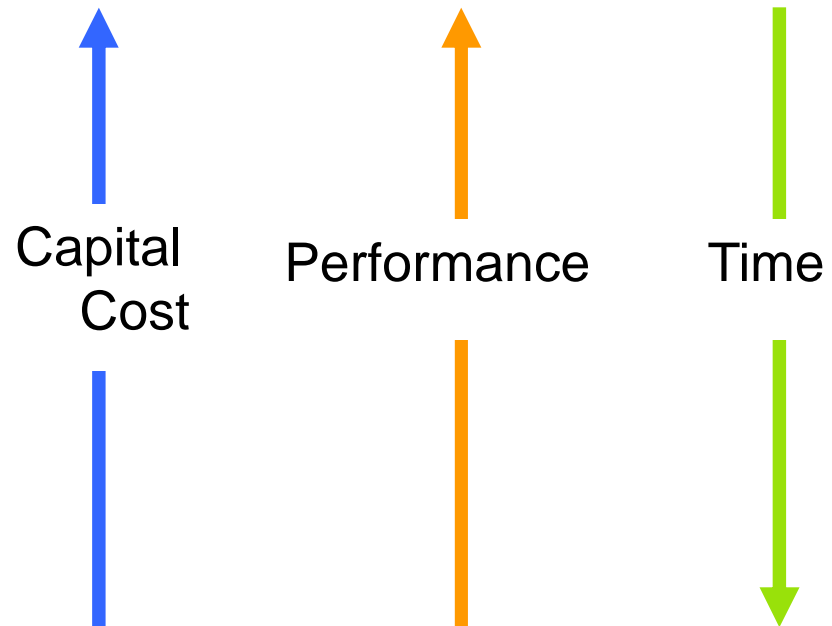
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- Low embankments

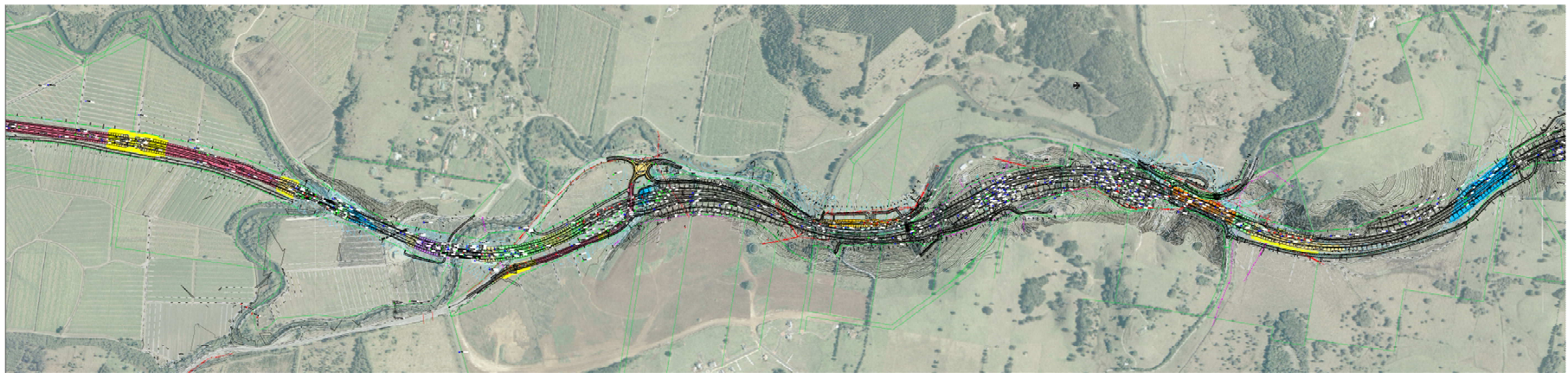
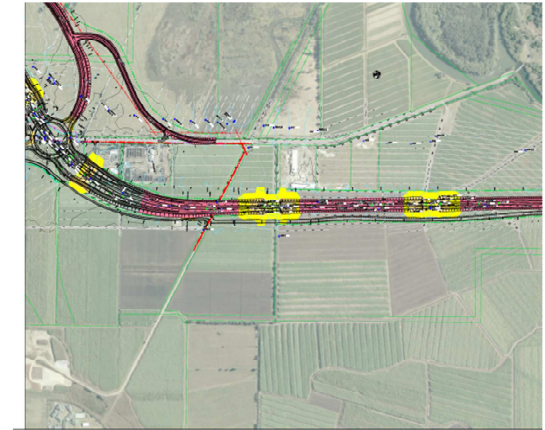
- Early construction of fill and long preloading periods
- Fill drainage channels with light weight material (e.g. Bottom Ash)

- High embankments

- Piled embankment
- Vacuum consolidation (VC)
- Stone columns (SC)
- Deep Dry soil mixing (DSM)
- Dynamic replacement (DR)
- Hybrid DSM & SWD
- Light weight fill (Bottom Ash, EPB)
- Surcharge and wick drains (SWD)
- Wet soil mixing (WSM) / Cutter soil mixing (CSM)
- Controlled modulus columns (CMC)
- Electro-osmosis



# EXTENSIVE AND VARIED GROUND TREATMENTS



## Low Embankment Strategy



When Used	Cost	Risks
<ul style="list-style-type: none"> <li>•Whole of life cost benefits</li> <li>•Long construction time available</li> </ul>	<p>Low &lt;\$100/m<sup>2</sup></p>	<ul style="list-style-type: none"> <li>•Settlement and rate of settlement may vary</li> <li>•Differential settlement affecting pavement performance</li> <li>•Instability due to rate of construction</li> <li>•Delay in construction programme</li> </ul>

# Stability berms / structural geofabric



When Used	Cost	Risks
<ul style="list-style-type: none"><li>• Enhance embankment stability</li><li>• Speed up construction (e.g. piling at FPBs)</li><li>• In combination with other ground treatment types for VFM</li></ul>	Low \$50- \$100/m <sup>2</sup>	<ul style="list-style-type: none"><li>• Instability due to rate of construction</li><li>• Delay in construction programme (as per surcharge only)</li><li>• Berms may increase flood impacts</li></ul>

# SURCHARGE AND WICK DRAINS



<b>Theory</b>	Consolidate clay by squeezing water out of void space
<b>When Used</b>	<ul style="list-style-type: none"> <li>•When time available at bridge approaches</li> <li>•Transitions from 'hard' treatment to achieve differential settlement criteria</li> <li>•Often in conjunction with berms and fabric</li> </ul>
<b>Cost</b>	Low \$100-\$300/m <sup>2</sup>
<b>Time</b>	Long
<b>Production</b>	>5000 lm/day per rig
<b>Risks / Constraints</b>	<ul style="list-style-type: none"> <li>•Settlement and rate of settlement varies (affecting performance and construction programme)</li> <li>•Instability due to rate of construction</li> <li>•Acidic water extrusion (usually minor volume)</li> </ul>

# DYNAMIC REPLACEMENT



<b>Theory</b>	<ul style="list-style-type: none"><li>• Enhance strength and stiffness of soils</li><li>• Consolidate clay by squeezing water out of void space (secondary action)</li><li>• Acts as drain as well as load transfer columns</li></ul>
<b>When Used</b>	<ul style="list-style-type: none"><li>• Shallow soft soils to ~6m depth</li><li>• Medium time available</li><li>• Reduce settlement</li><li>• Enhance stability</li></ul>
<b>Cost</b>	Low to Medium ~\$300-\$500/m <sup>2</sup>
<b>Production</b>	
<b>Time</b>	Medium
<b>Risks / Constraints</b>	<ul style="list-style-type: none"><li>• Settlement and rate of settlement varies</li><li>• Ground heave during installation</li><li>• Vibration / aerial debris / operation near live traffic</li></ul>

# DYNAMIC REPLACEMENT WITH WICK DRAINS



# STONE COLUMNS



<b>Theory</b>	<ul style="list-style-type: none"><li>•Enhance strength and stiffness of soils</li><li>•Consolidate clay by squeezing water out of void space (secondary)</li><li>•Acts as drain as well as load transfer columns</li><li>•Wet / dry installation</li></ul>
<b>When Used</b>	<ul style="list-style-type: none"><li>•Medium time available</li><li>•Reduce settlement</li><li>•Enhance stability</li><li>•Balance rig availability in programme</li><li>•Environmental control</li></ul>
<b>Cost</b>	Medium ~\$300-\$600/m <sup>2</sup>
<b>Time</b>	Medium
<b>Production</b>	130lm/day/rig
<b>Risks / Constraints</b>	<ul style="list-style-type: none"><li>•Settlement and rate of settlement varies</li><li>•Water used in wet method requires treatment in acidic soils</li></ul>

# VACUUM CONSOLIDATION



<b>Theory</b>	<ul style="list-style-type: none"><li>• Consolidate clay by squeezing water out of void space under vacuum and surcharge</li><li>• Accelerate settlement</li><li>• Enhance stability</li></ul>
<b>When Used</b>	<ul style="list-style-type: none"><li>• Less time available than required for SWD</li><li>• Limited space for stability berms etc</li><li>• Deep uniform clay deposits (Menard)</li><li>• Beaudrain system also available</li></ul>
<b>Cost</b>	Medium to high \$300 - \$500/m <sup>2</sup>
<b>Time</b>	Medium
<b>Risks / Constraints</b>	<ul style="list-style-type: none"><li>• Settlement and rate of settlement varies</li><li>• Instability due to rate of construction (less than SWD)</li><li>• Acidic and heavy metal water treatment (at Ballina)</li></ul>

# DRY DEEP SOIL MIXING



<p><b>Theory</b></p>	<ul style="list-style-type: none"> <li>• Enhance strength and stiffness of soils through cementation</li> <li>• Act as load transfer columns</li> <li>• Wet / dry installation</li> </ul>
<p><b>When Used</b></p>	<ul style="list-style-type: none"> <li>• Short time available (eg Bridge Abutments)</li> <li>• Reduce settlement</li> <li>• Enhance stability</li> <li>• Create tapered transitions</li> <li>• Hybrid with SWD</li> <li>• Dry mixing for embankments &lt; 6m high</li> <li>• Wet mixing for embankments &gt; 4m high</li> </ul>
<p><b>Cost</b></p>	<p>Medium (DSM) to high (WSM)</p>
<p><b>Time</b></p>	<p>Short</p>
<p><b>Production</b></p>	<p>800mm dia. 300lm/day/rig 600mm dia. 600lm/day/rig</p>
<p><b>Risks / Constraints</b></p>	<ul style="list-style-type: none"> <li>• Field trials critical to success</li> <li>• Variability in strength and stiffness of column (Dry more than wet)</li> <li>• Required cement content</li> <li>• Limited rig availability</li> <li>• Few market participants</li> <li>• Limited Australian experience</li> </ul>

# DRY DEEP SOIL MIXING





<p><b>Theory</b></p>	<ul style="list-style-type: none"> <li>•Transfer loads to stiffer soils</li> <li>•Enhance column/soil resistance through soil displacement</li> <li>•Load transfer platform required (usually reinforced granular mattress) unless columns installed at close spacing</li> </ul>
<p><b>When Used</b></p>	<ul style="list-style-type: none"> <li>•Short time available</li> <li>•Reduce settlement to small levels</li> <li>•Low risk of exceeding design criteria</li> <li>•Typically at bridge approaches</li> </ul>
<p><b>Cost</b></p>	<p>High \$500-\$1000/m<sup>2</sup></p>
<p><b>Time</b></p>	<p>Short</p>
<p><b>Risks / Constraints</b></p>	<ul style="list-style-type: none"> <li>•Damage during installation at close spacings</li> <li>•Differential settlement of transitions to soft ground</li> <li>•Potential impact on adjacent structures due to ground displacements</li> </ul>

# Light weight fill



<b>Theory</b>	<ul style="list-style-type: none"><li>•Reduce loading on ground (BA = 2/3 and EPB &lt; 1/60 weight of normal fill)</li><li>•Reduce settlement</li></ul>
<b>When Used</b>	<ul style="list-style-type: none"><li>•Short time available</li><li>•Reduce settlement</li><li>•Contingency measures</li><li>•EPB at bridge approaches (eg Port of Brisbane Motorway)</li></ul>
<b>Cost</b>	Medium (Bottom Ash \$200-\$400/m <sup>2</sup> ) to high (EPB)
<b>Time</b>	BA – Medium to long if preload required EPB - Short
<b>Risks / Constraints</b>	<ul style="list-style-type: none"><li>•Transportation distance from source to site (BA)</li><li>•Contamination / Leachate (BA)</li><li>•Chemical damage (EPB)</li><li>•Long-term creep (EPB)</li></ul>

# GEOTECHNICAL OUTCOMES

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- Embankment settlements during construction up to 6.5m
  - Opened on budget
  - Performance achieved on average
  - Opened 6 months early
  - Development of ground treatment specs for RMS
  - Ballina Field Testing Facility
  - Transfer of knowledge to RMS and industry
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# Acknowledgements

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