Permeable Interlocking Concrete Pavement
A Low Impact Development Tool
Training for Municipal Officials

Presented by:
Interlocking Concrete Pavement Institute
The Low Impact Development Center, Inc
North Carolina State University

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Learning objectives:

- Identify PICP Components
- Understand PICP benefits to urban hydrology & water quality
- Understand the hydrological design principles for the pavement base/subbase
- Obtain ideas for integrating PICP into municipal design, planning and zoning regulations

Contents

- PICP Materials & System
- Low Impact Development & PICP
- PICP Design, Construction, Maintenance & Costs
- Meeting Planning Objectives
  - Stormwater Regulations
  - LEED® Credits
  - ADA Compliant
  - Improved Tax Base
  - Infrastructure Cost Savings
  - Green Streets
- Additional Resources
What is PICP?

Concrete Pavers
Permeable Joint Material
Open-graded Bedding Course
Open-graded Base Reservoir
Open-graded Subbase Reservoir
Underdrain (As required)
Optional Geotextile Under the Subbase
Uncompacted Subgrade Soil

System Components

What is PICP?

Paver Types

- Notched corners or sides
- Interlocking Shapes
- Built-In Concrete Joint Spacers
  - Enlarged Joints: up to ½ in. (13 mm)
- Porous block, not for freezing climates, use enlarged joints
What is PICP?
Paver Types: Interlocking Shapes/Patterns

Changed Hydrology
LID: An Innovative Approach

Minimize the hydrologic impacts of development

LID & Stormwater Management
Low Impact Development (LID) Principles

- Work with the landscape
- Focus on prevention
- Micromanage stormwater on the site
- Keep it simple
- Multi-functional landscapes
- Use LID tools such as PICP
LID & Stormwater Management
Treatment Train Site Design

1. Source controls = Infiltrate
2. Conveyance controls = Filter & detain
3. End of Pipe Controls = Retain in ponds, streams or storm sewer
LID & Stormwater Management

PICP, LID & Municipal Goals
- LID is a flexible strategy
- PICP is an adaptable tool

Subdivision Design for Watershed Recovery

Glen Brook Green Subdivision
Waterford, CT
Jordon Cove Watershed
US EPA Section 319 NMP
Municipal Design Goal: Watershed Recovery
Strategy: LID Development
Tools: PICP and other Permeable Pavements
### Water Quality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Asphalt</th>
<th>PICP</th>
<th>Stone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff depth, mm</td>
<td>1.8</td>
<td>0.5</td>
<td>0.04</td>
</tr>
<tr>
<td>TSS, mg/L</td>
<td>47.8</td>
<td>15.8</td>
<td>33.7</td>
</tr>
<tr>
<td>Nitrate nitrogen, mg/L</td>
<td>0.6</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Ammonia nitrogen, mg/L</td>
<td>0.18</td>
<td>0.05</td>
<td>0.11</td>
</tr>
<tr>
<td>Kjeldahl nitrogen, mg/L</td>
<td>8.0</td>
<td>0.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Total Phosphorous, mg/L</td>
<td>0.244</td>
<td>0.162</td>
<td>0.155</td>
</tr>
<tr>
<td>Copper, ug/L *</td>
<td>(13/9)</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Lead, ug/L *</td>
<td>(65/2.5)</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Zinc, ug/L *</td>
<td>(120/120)</td>
<td>87</td>
<td>25</td>
</tr>
</tbody>
</table>

Mean weekly pollutant concentration in stormwater runoff from asphalt, PICP and crushed stone driveways

* Metals: (acute/chronic) toxicity to freshwater aquatic life

### Design Considerations

- Soil infiltration rates
- Base reservoir capacity
- Slope
- Design for Full or Partial infiltration or Water Harvesting
Location Considerations

AVOID:
- Drinking water wells (100 ft. [30 m] min. distance)
- High water tables
- High depth to bedrock
- Industrial sites, fueling stations
- Expansive and fill soils
- Increase in impervious cover after permeable pavement - exceed storage/filtering capacity; size for build-out

NC State University
Research Indicates:
- Not exposed to fines:
  - 800 in./hr (20,000 mm/hr)
- Exposed to fines:
  - 3.1 in./hr (80 mm/hr)
  - PICP infiltration rate similar to surrounding soil
Long term surface infiltration depends on sediment deposition rates + vacuum maintenance
German studies: long term (15+ yr.) surface infiltration is ~15% of initial

Exfiltration Design
Low Permeability Soils

- Exfiltration: water loss to underlying soil
- Aggregate is washed to prevent clogging of underlying soil
- Exfiltration limited by permeability of underlying soil
- When an underdrain is required, leave a gravel storage layer below underdrain to encourage exfiltration

Clay In-Situ Soils

Considerations
- Reduction in peak flows still likely
- Lower reduction in runoff volume
- Extra aggregate required for strength & storage
- Underdrain system required
- Impermeable layer required at the bottom for shrink-swell clays
PICP Design

- Design software is available
- Software incorporates:
  - Hydrologic Design
  - Structural Design
- Contact ICPI to obtain software

What To Look For
Subgrade & Base Preparation
Construction
Paver Installation

What To Look For
Joint Aggregate Installation
What To Look For: Design Details
Overflow and Concrete Edge Restraints

 Overflow Drain  Drain to Grass Swale

Maintenance

- Annually: inspection of observation well after major storm, vacuum and sweep surface – improves infiltration
- Maintenance checklist
- Model maintenance agreement
- Monitor adjacent uses
Maintenance
Sweeper Effectiveness

Best: Vacuum sweeper (no water)

OK: Regenerative air (broom) sweeper (no water)

Vacuum essential as brush bristles clean ~ ¼ in. into surface

Educational Materials Explain Concepts and Encourage Pollution Prevention

Allowing PICP as a BMP promotes use
## Costs

Autumn Trails, Moline, IL 2006

<table>
<thead>
<tr>
<th></th>
<th>PICP</th>
<th>Concrete</th>
<th>Asphalt</th>
</tr>
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<tbody>
<tr>
<td>Cost per sf</td>
<td>$10.95</td>
<td>$15.00</td>
<td>$11.50</td>
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~ 39,000 sf

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## PICP Benefits

- Conserves space: pavement as detention
- Clogged openings easily refreshed
- Design as infiltration trench w/ pavement
- Can meet stormwater detention pond design requirements
- 100% runoff reduction for 85-90% of storms
- NRCS CN 45 to 85
- Rational Method ‘C’ value 0.25 to 0.35
Green Infrastructure Benefit
PICP on Structural Soil Supports Tree Growth

Pier A Park
Hoboken, NJ, 1998
Image courtesy of Bruce K. Ferguson

LID Designs for Urban Land Uses

Enhanced Curb Appeal and SW Treatment
Parking Lot Reconstruction Handles Stormwater
Replaces Detention Pond
LEED Gold Project
EPA 319 Project
LID and PICP
Attractive, Durable, Flexible, Accessible and Sustainable

Promotes Tree Health  Reduced Deicing Costs  Retrofit for Water Quality

Demonstration Project  ADA Compliant

Integration of Sustainable Practices for Urban Land Uses

Safety Island  Parking Lots: double as detention area with storage

Storm Sewers Eliminated  Pilot & Retrofit LID Projects
PICP Meets Multiple Planning Objectives

- **Green Streets Programs**
- **Stormwater Regulation**
- **LEED Project Material**
- **Infrastructure Cost Savings**
- **Improved Tax Base**
- **Durable ADA Compliant Surface**
**Stormwater Management Objectives**

...Varies with locality...

*Water Quantity*
- Retain/infiltrate runoff volumes & peak flows
- Imitate pre-development conditions
- Control amount of impervious cover
- Stormwater utility fees

*Water Quality*
- Capture percentage of storms
- Control specific nutrients, metals

*PICP addresses all objectives*

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**Runoff & Pollution Reduction**

**Case Study**
Jordan Cove Watershed, Glen Brook
- Green subdivision, Waterford, CT
- EPA Section 319 National Monitoring Program – 10 year program
- PICP driveways on dense-graded, crushed stone base
- Runoff & pollutants compared to PICP asphalt & aggregate driveways in 2002-03
Regulatory Approaches Encouraging PICP

- Update BMP manuals
- Ordinance language
- Demonstration projects
- Expedited permitting
- Tax credits
- SWM fee rebates
- Coordinated efforts between governmental agencies

PICP can be incorporated into meeting the zoning and land development regulations

- Permit alternative roadway designs – Chicago, IL, Portland, OR
- Consider performance standards rather than dimensional requirements – Madera FL
- Capital Region District (Victoria, BC) includes Permeable Pavement, including PICP, in its Watershed Protection recommendations in the LID section.
Ordinance Language Directs Development

- Form based codes can specify LID tools such as PICP (Seattle)
- BMP lists can be expanded to include permeable pavements (Chicago – funded Green Alleys with Menu Money)
- Performance standards required (Bluffton, SC) – 50% of parking lots and 100% of over-flow parking lots to be pervious and infiltrate first inch of runoff and monitor turbidity

Kane County, IL 23,000 ft² (3623 m²) demonstration of new SW Ordinance BMP for water quality

Parking and Water Regulatory Needs Accommodated

PICP allowed by Town Council - supported as environmentally friendly pavement option
PICP Meets Multiple Planning Objectives

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PICP Benefits
PICP contributes to LEED Credits

- Decrease pollution through sustainable sites (SS)
- Increase building water use efficiency (WE)
- Reduce energy and atmospheric pollutants (MR)
- Conserve materials and resources (MR)
- Improve indoor air quality (EQ)
- Offer innovative ideas and designs (ID)
### PICP Benefits

**Decrease Pollution Through Sustainable Sites (SS)**

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED® Points</th>
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<tbody>
<tr>
<td>6.1 Reduction of stormwater rate and quantity</td>
<td>1</td>
</tr>
<tr>
<td>6.2 Treatment of stormwater runoff</td>
<td>1</td>
</tr>
<tr>
<td>7.1 Increase albedo (reflection of solar radiation) (non-roof surfaces)</td>
<td>1</td>
</tr>
<tr>
<td>7.2 Increase albedo (segmental paver on roof surface)</td>
<td>1</td>
</tr>
</tbody>
</table>

### PICP Benefits

**Conservation of Materials and Resources (MR)**

Credits - 1 LEED® point each:

<table>
<thead>
<tr>
<th>Credit</th>
<th>Description</th>
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<tbody>
<tr>
<td>3.1</td>
<td>5% reused content (i.e. crushed concrete)</td>
</tr>
<tr>
<td>3.2</td>
<td>10% reused content</td>
</tr>
<tr>
<td>4.1</td>
<td>5% recycled waste content (i.e. flyash)</td>
</tr>
<tr>
<td>4.2</td>
<td>10% recycled waste content</td>
</tr>
<tr>
<td>5.1</td>
<td>20% manufactured regionally (&lt;500 mi.)</td>
</tr>
<tr>
<td>5.2</td>
<td>50% materials extracted regionally (&lt;500 mi.)</td>
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[ICPI Tech Spec 16](#)
PICP Meets Multiple Planning Objectives

- Green Streets Programs
- Stormwater Regulation
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- Durable ADA Compliant Surface

PICP Benefits

ADA Compliant

PICP handicapped parking over stormwater detention system
Burnaby, BC
PICP Meets Multiple Planning Objectives

- Green Streets Programs
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- Durable ADA Compliant Surface
- Infrastructure Cost Savings

Save on Infrastructure costs while Protecting Lake Water Quality

- Ultra-Urban settings gain water quality benefits from PICP
- PICP reduces runoff volume

South Lake Union Street Car Facility, Seattle, WA
Robson Center, Gainesville, GA
Tax Base Enhancement: Example System Costs

Assumptions:
- Paver Thickness: 3 in. (8 cm)
- Bedding Layer: 2 in. (5 cm)
- Base Layer: 8 in. (20 cm)
- Total Area: 15,000-20,000 ft² (1,500 to 2,500 m²)
- Prevailing Wages
- Does NOT include design, concrete curbs, excavation, and pipe costs
- $ 7-12/sf

PICP Meets Multiple Planning Objectives

- Green Streets Programs
- Stormwater Regulation
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Future Forecast

- Aging, expanding infrastructure
- Growing population and even faster rates of land development
- Global warming increasing size of storm events, flooding, and droughts
- Very tight wastewater infrastructure budgets

Gap in Funding for Repairs of and Upgrades to Aging Infrastructure

- Clean Water SRF enacted funding for 2007 was the lowest in a decade, but may be turning around this year
- EPA estimates $20 billion annual funding gap
$3.5 million project - $400 K cost savings
US Cellular Field, 2008

- Used permeable paving because of the many benefits it offers and because it meets the new 2008 Chicago Stormwater Management Ordinance.


- Reduces or even eliminates runoff and improves water quality.


US Cellular Field
20,000 ft²/day (2400 m²/day)
6.1 A (.57 ha)

Saving the water supply one parking lot at a time

527,616 permeable interlocking paver units installed

PICP Meets Multiple Planning Objectives

- Durable ADA Compliant Surface
- Stormwater Regulation
- LEED Project Material
- Improved Tax Base
- Infrastructure Cost Savings
- Green Streets Programs

Municipal Goals

- Low Impact Development (LID) Potential
  - Livable Communities
  - Durable Hardscape
  - Stormwater Management
  - UHI - Cool Pavements
  - Hydrologically Functional Development
**Issues:** Buildable land, infrastructure cost savings

**Tool:** PICP

Burnaby, BC

Hilton Head, SC

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**Chicago Green Alley Program**

**Issue:** Flooding and CSO reduction

**Strategy:** LID Retrofit Pilot Programs

**Tool:** PICP

Images courtesy of Chicago Department of Transportation
Seattle Green Factor
Integrated plan signed into law Dec 21, 2006

- Land Use Code defines building forms and density; minimizes impacts of new development
- PICP supports landscape efforts

LID with PICP

Union Station: Office parking

High Point: Affordable Housing

James Guerrero Architect: Commercial Office

Wedge Park Phase II: Recreation Parking
Make It Happen In Your Community

- Pass a stormwater management law that includes PICP in the stormwater BMP toolbox
- Create demonstration projects
- Collaborate with property owners, developers, and engineers to find application opportunities for PICP
- Reexamine open space standards and determine how PICP fits in these standards

PICP Resources

- Fact Sheets
- Design manual
- Design software
- Presentations

www.icpi.org
www.ncsu.edu/picp
www.lowimpactdevelopment.org
Questions?