RESEARCH PROPOSAL

TOPIC: Alternatives for handling stormwater runoff from
disconnected downspouts in urban cold climate areas.

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SCHOOL FOR NEW LEARNING

(Research Seminar)

Competencies:

L-8: Can pose questions and use methods of formal inquiry to answer questions and solve problems.

L-9: Understands natural and artificial stormwater handling with respect to the implications and basic functions of stormwater catchment, containment, and control.

I. The Problem and Its Setting

A. Statement of the Topic to be Explored:

The topic that I am exploring is Knowing Neighborhoods. The problem within this topic that interests me is how changing government regulations have created safety hazards in neighborhoods.

In the natural world stormwater, precipitation from the sky in the form of rain, snow, and ice, falls to the earth and is absorbed into the ground. The ground is permeable and allows for the water to infiltrate, flowing down and filtering through it to sub-surface waters. The sub-surface waters connect with aboveground waters - lakes, ponds, rivers, streams, and oceans – from below the surface and flow into them in a controlled, natural manner.

The increased building density in urban areas has decreased the amount of available land to absorb stormwater and increased the amount of impervious surfaces (Residential Storm Water Management 8). Impervious surfaces, such as concrete and asphalt, prevent infiltration of water into the ground, increase the amount of stormwater runoff, overwhelm sewer systems, and lead to flooding. Stormwater that cannot be absorbed into the ground and runs off through sewer systems provides a concentrated flow of water, along with the pollutants it washes off of surfaces. This stormwater has historically flowed directly into waterways, or through stormwater or combined (wastewater and stormwater) sewer systems.

In municipalities that use combined sewer systems, wastewaters piped from buildings and stormwater runoff mix together and are, ideally, directed to wastewater treatment plants. The amount of man-made waste can be fairly well predicted and managed by treatment plants. The amount of stormwater runoff is dependent on the quantity of precipitation in any given storm-event – rain, snow, or ice. A large amount of stormwater runoff can result in excess capacity and overflow of the system. The overflow means dumping the excess of the combined man-made waste and stormwater into waterways such as lakes, ponds, rivers, streams and oceans, polluting these waters and, possibly, causing downstream flooding (Butler and Davies 17-26).

When stormwater cannot infiltrate the ground surface and does not flow into some type of containment system, such as a sewer, it runs off whatever surface it lands on and flows toward the lowest point. This can create a stream enhancing larger bodies of water, overwhelming their capacity and causing flooding.

In 1948 the Federal Government of the United States enacted the Federal Water Pollution Control Act, its stated purpose being to "enhance the quality and value of our water resources and to establish a national policy for the prevention, control and abatement of water pollution." This law has been repeatedly amended and, by 1977, became colloquially known as “The Clean Water Act.” It has expanded from legislating commercial and industrial pollutants in major water bodies to point source discharge of pollutants - including stormwater runoff.

One response to the changes in the Clean Water Act is to require that downspouts be disconnected from the combined sewer systems, such as the municipality of Portland, Oregon did in 1993, reducing yearly stormwater flow to the combined sewer systems by almost one billion gallons (Portland Oregon). This will help reduce the pollution and capacity overload of waterways from combined wastewater and stormwater sewers, but it can create a public safety hazard. In high-density, urban areas, existing buildings are designed to drain stormwater from roofs into sewers. Many buildings do not have enough land capacity to provide storage (cisterns) or permeable ground surface to accept stormwater runoff from roofs. During periods of freezing temperatures this is a serious public safety concern. Stormwater melting from roofs freezes on the ground and creates icy patches, which can be a slip hazard.

Pervious concrete surfaces permit storm water runoff to infiltrate (filter through) the ground (National Ready Mixed Concrete Association). This should reduce the incidence of icy patches caused by stormwater runoff in cold weather climates. Although, where these benefits are achieved is not a matter that has been studied in-depth.

I propose to investigate whether installation of pervious concrete pads will provide the necessary containment and ground infiltration during freezing temperatures to prevent the hazard caused by downspout disconnection. The research I propose will cover only existing, high-density, urban, residential properties that have gutters and downspouts. The study will be in the Midwest region of the U.S.A. where there routinely are winter storms resulting in measurable precipitation and temperatures going below freezing.

B. Statement of the Problem and Sub-problems within the Topic to be Addressed:

The problem that I propose investigating is: Drainage from disconnected downspouts in high-density residential urban areas cannot infiltrate into natural soil surfaces during freezing weather, drains onto walkways, refreezes, and creates a hazard to pedestrians.

C. Statement of the Questions about the Problem that Research will Answer:

The question I propose researching is: How well can pervious concrete provide containment and ground infiltration of stormwater runoff from downspouts in cold weather climates in high-density, residential urban areas during freezing temperatures?

D. Statement of the Hypothesis that the Research will Test:

The hypothesis that I propose testing is: Pervious concrete will provide adequate containment and ground infiltration of stormwater runoff from downspouts in cold weather climates in high-density, residential urban areas during freezing temperatures.

E. Delimitations

I am not considering options for stormwater control or containment, such as rain barrels, cisterns, bogs, swales, artificial lakes, ponds, drainage ditches, or construction of stormwater-specific sewer pipelines.

Areas, zones, and structures including, but not limited to, rural, non-urban, low-building density, non-residential, commercial, industrial, fields and parking lots are not being considered.

Watershed protection districts or flood control districts are not covered in my research.

I am not studying regions that are dry or desert, or where snow, ice or freezing rain, and temperatures at 32 degrees Fahrenheit and below are not the norm for the months of December through March.

I am not considering man-made water runoff that results from farming irrigation and sprinkling, gardening, lawn care, etc.

I am not measuring for contaminants in the water.

I am not evaluating water quality after infiltration through the soil.

F. Definitions of Terms

Average city block: approximately 100,000 sq. ft. (City Blocks Differ in Size).

Cold weather climates: areas where average annual sustained temperatures are 0 to 40 degrees Fahrenheit from November through February.

Freezing temperatures: 0 to 32 degrees Fahrenheit.

Ground infiltration: water soaking into the ground as measured using underground collection systems.

High-density area: an area of a municipality with a large concentration (20-30 per average city block) of one- to four-family residentially-zoned buildings, with or without detached or attached garages, in close proximity to each other, on lots approximately 30’-50’ wide x 100’-150’ deep (.07-.17 acres).

Pervious concrete: porous pavement that allows water to infiltrate through and into the ground.

Provide adequate containment: keep the water flow inside the set boundaries of the container.

Residential urban area: a community of one- to four-family residentially-zoned buildings, with or without detached or attached garages, spaced within 10 to 15 feet of each other.

Stormwater: Water falling to natural and artificial surfaces on the earth, from the sky, as rain, snow, sleet, or ice. The term stormwater is used as one and two words throughout research literature, I will use it as one unless otherwise written in a source.

Stormwater runoff: the water flowing off catchment surfaces, specifically from rooftops through downspouts, during and immediately following a rainfall, or from melting ice or snow.

G. Assumptions

The proposal developed here is based on the following assumptions:

there will continue to be storm water runoff,

freezing temperatures will continue to cause ice to form,

natural soil will freeze when temperatures are sustained at 32 degrees Fahrenheit or below.

stormwater runoff will not infiltrate into natural soil that is frozen.

II. Review of the Related Literature

A. Major Issues Explored by Scholars who have Researched this Topic and Problem

It is reported that every day in the U.S. nearly a quarter of the fresh water available, approximately 340 billion gallons, is removed for business, personal, and recreational use. The amount returned to the waterways is approximately 65% of that withdrawn and some, but not all, is treated to remove pollutants (LEED for New Construction and Major Renovations 115).

The U.S. Environmental Protection Agency has been charged with regulating and reducing pollution of U.S. waterways. Their studies have found that the capacity of combined sewer systems (handling both sewage and storm water) and water treatment plants are overwhelmed by the volume taken in during periods of heavy rain or melting snow. During these periods the excess volume, that which cannot be handled by the system, is discharged into waterways that provide fresh water, food, and recreation, contaminating them (United States Environmental Protection Agency Dept. of Water, Combined Sewer Overflows).

To reduce the pollution, the pressure on the sewer systems needs to be alleviated. To achieve this goal, the U.S.E.P.A. has created numerous regulations, including mandating municipalities to reduce stormwater runoff from private properties. In its "Managing Wet Weather with Green Infrastructure Municipal Handbook," the U.S.E.P.A. states that downspout disconnection is:

> breaking the direct link between impervious areas such as roofs or paved surfaces and the storm or combined sewer system. Disconnection can reduce combined sewer system overflows; reduce potable water demand when the runoff from roofs is used for applications such as landscape irrigation and toilet flushing; recharge ground water, helping to restore the natural hydrologic cycle; reduce stormwater discharges to waterways; and reduce or eliminate the need for large, municipally owned stormwater management facilities. (7)

But the U.S.E.P.A. does not take into account the additional burdens downspout disconnection creates on neighborhoods when the stormwater it redirects from impermeable rooftop surfaces flows and freezes on the impermeable ground-level surfaces.

The problem with downspout disconnection is that most buildings in high-density urban communities are closely spaced and do not have an area for water runoff to infiltrate into the ground before it runs onto walkways. In freezing temperatures, especially when the ground is frozen and there is less opportunity for ground infiltration, the runoff becomes ice and creates a slip and fall hazard for pedestrians. My intent is to test my hypothesis that the use of pervious concrete is the solution for downspout stormwater collection in high-density, residential communities in cold weather climates that experience freezing temperatures.

Reviewing the literature has shown me that there are many ideas and methods for dealing with stormwater runoff. There is economically incentivizing control, as put forth by Thurston, but that only works if there are options for control (89-96). There is collection – under- and aboveground cisterns, rain barrels, swales and retention ponds – but most are not viable options for the small real estate parcels in highly built-up urban areas. The aboveground collection devices, such as cisterns and rain barrels, are subject to freezing and rupture, which makes them a poor option in freezing temperatures. Given the close proximity of the buildings and small land areas not covered by buildings, underground trenching and construction is generally not a viable option for the subject land parcels. The stone-lined swale, in-ground but not below, is one of the stormwater runoff devices commonly used in cold northern climates and it is the only system in the study by Roseen, et al. that showed a significant reduction in performance in freezing winter temperatures; he attributes this to snow and ice coverage (131). Even if the swale worked, it is not workable for the type of neighborhoods I propose looking at through my research.

Based on the studies I have read, infiltration into the ground is an essential component of stormwater management. Not only does ground infiltration alleviate the stress on the combined sewer systems, it also replenishes the underground water tables (Davy, 1). Pervious concrete appears to be an appropriate solution because it "has an infiltration rate far exceeding any expectation of precipitation rate" and it performed significantly better in freezing temperatures than did the untreated control plots of grass covered soil (Tyner, et al. 2636-2641).

In the studies "Long-Term Stormwater Quantity and Quality Performance of Permeable Pavement Systems," "Seasonal Performance Variations for Storm-Water Management Systems in Cold Climate Conditions," and "Increasing exfiltration from pervious concrete and temperature monitoring," the authors show that determining the amount of stormwater runoff that actually occurs is critical and will necessitate actual measurements taken from numerous sites during multiple storm events during winter months (Brattebo and Booth), (Roseen, et al. 128-137) and (Tyner, et al. 2636-2641). Numerous studies and models are available for determining runoff, but their accuracy in application to other studies is undermined by the lack of consistency in standards and modeling, as revealed in a study in Water Research (Park, et al. 2773-2786). In order to create a model that will be accurate and transferable for future studies, measurements will need to be collected at each site for the actual total precipitation of each precipitation event, the surface area of the roofs the downspouts are collecting water from, and the quantity of runoff that is directed through the downspouts.

Air temperature and ground temperature are important variables in this testing and measurements will need to be made prior to and during the precipitation events. Sansalone and Teng found that evaporation rates were significantly higher in summer than in winter, so their pervious test material contained almost 40% more water after three days in the summer versus winter experiments (1166). This indicates that I may need to take other variables, such as evaporation, into consideration in my research.

The studies I have reviewed have provided a significant amount of understanding on how my research should and should not be pursued, as well as the importance of actual measurements as opposed to assumptions and borrowed models. They have given me information that is specific enough to make general assumptions, but I cannot be certain that the results would be applicable to the situation I am investigating. Tyner believed, and showed, that conclusions from a study of freeze-thaw testing of pervious concrete in a laboratory did not apply to his studies on test plots in actual outdoor weather conditions (2636). I believe that experiments must be performed using pervious concrete in actual real-life situations and that there will be a positive outcome.

The existing literature provides some useful research on the subject of the use of pervious concrete. Some studies have been conducted on pervious concrete in test plots on flat surfaces in open spaces or in laboratories separate from outdoor variables. Unfortunately, the research I have found has not been applied directly to residential properties in a high-density urban area.

None of these studies investigated small surface areas that would be found along side a one- to four-family residence on a small urban lot. Nor did they measure the amount or rate that stormwater in the form of ice or snow melt-off from a roof, drains through a downspout and then flows elsewhere, or whether it infiltrates into frozen ground. I still do not know if placement of a pervious pad on such an area would direct this stormwater to infiltrate into the ground or what the best design would be. Would the solar effect on the large pads in these studies occur with smaller pads? Would a lack of direct sunlight negate any infiltration benefit? Would the smaller pads be too small? What is the smallest pad area that would work? These are questions I might eventually seek to answer.

B. Methodologies Utilized by Scholars to Research this Topic and Problem

"Urban Storm-Water Quality Management: Centralized versus Source Control," is a longitudinal study that investigates several models of stormwater management, including infiltration on natural unaltered ground, from numerous rainfall events over a six-year period (Freni, et al. 268-278). To understand the capacity of the soil for infiltration of stormwater (the soil permeability), the authors carried out pre-study site surveys and performed field experiments as well as measurements in the laboratory. The researchers used measurements, calculations, and observations to analyze the affects of stormwater on different models in a quantitative study. This helps me to understand and model soil testing for infiltration.

Benjamin Brattebo and Derek Booth created a longitudinal study of water infiltration of different types of surfaces (1-15). The materials to be studied were installed in parking spaces that were used by office workers during regular working hours and, generally, clear nights and weekends. Permeable and impermeable materials were used as test and control, respectively. The site was chosen because the soil had tested well for infiltration; soil impermeability could have impaired performance of permeable pavement. Water samples that ran off through pipes were collected and tested for both quantity and quality of the stormwater runoff from 15 different storms. This was a quantitative study that used measurements, laboratory testing, and observation of the different models. This helps me in designing the setup, collection methods, and measurements that I might use in my research.

Robert M. Roseen, et al., evaluated six different LID (low-impact development) systems, including porous asphalt, to see how they performed in cold climates (128-137). These researchers used a parking lot that had daily use. The research was correlational and longitudinal for 27 stormwater runoff events over two years. For each storm event, the systems were tested for: stormwater runoff, duration, intensity, peak flow, volume, air and ground temperature, preceding dry period, water quality, and watershed loading. This was a quantitative study that used measurements, laboratory testing, and observation of the different models. The authors attempted to correlate the amount of stormwater infiltration that occurred to the temperature. This helps me in designing the setup, collection methods, and measurements that I might use in my research.

In “Increasing exfiltration from pervious concrete and temperature monitoring,” J.S. Tyner indicated that he had already concluded that pervious concrete has good infiltration (2636-2641). Based on this understanding he prepared a correlational and longitudinal study to evaluate how to improve it. He prepared 12 plots of land, three untreated control and three each of a different surface preparation – all randomly placed within the test area, but no two of the same were next to each another. The different surface preparations were his independent variables testing what, if any, difference they made. Soil samples were taken and pre-test measurements of water flow, porosity, and infiltration were done to assess for variables that had not been considered. During this quantitative study, sensors recorded the temperatures of the concrete, the base, and the air; tests were performed on the concrete to check for the presence of water in the pores; and water infiltration into the sub-soil was measured. This helps me in designing the setup, collection methods, and measurements that I might use in my research.

Sansalone and Teng studied retention of stormwater runoff from an impervious roadway surface to the shoulder area of the road (1155-1167). This was a quantitative and longitudinal study using “relationships for water retention and hydraulic conductivity (1157). Quantities of rainfall were measured, as was stormwater collecting at the shoulder and either overflowing the curb or entering the pervious concrete and then infiltrating the ground. They also measured water quality as a result of the infiltration process (removal of pollutants). This study caused me to think about how the dependent variables I have not considered may affect my research and to make sure that I do identify as many as possible.

These positivist studies are all quantitative and longitudinal, necessitated by the subject(s) being studied. Real-world weather conditions, repeated stormwater collection events, freezing temperatures, and ground infiltration all require time and outdoors space. All of these studies were completed in natural weather conditions looking at cause and effect.

As descriptive research, the authors of these studies had already reviewed exploratory research and were building on it. They were looking at stormwater infiltration measurements and how different models, measures, and other variables affected them. Dependent variables included such things as quantity of water from a storm event and how long it lasted, temperatures of ground and air, and wind-effect.

The independent variables were the surface types: pervious, impervious, natural or artificial, and ground preparation.

Three of the studies correlate the stormwater infiltration rate to cold temperatures, which I will be doing. Some other previous tests of freezing temperatures on pervious concrete have been done in laboratories; the effects of sun and ground heat being absorbed by the concrete were not replicated there.

Three of the studies used sites that were subject to urban-life variables – cars being driven and parked on the surface. This was important because vehicles carry dirt and grime, drip oil and other pollutants, and other debris gets trapped under them; the vehicle weight and movement might cause collapse of the materials; any or all of these might fill in the pores of the pervious surface and diminish its effect.

In these three studies - Brattebo and Booth, Roseen, et al., and Sansalone and Teng - the presence of cars is a significant variable that I do not feel was given full weight. Sansalone and Teng accounted for an approximately 50 mile per hour wind-effect of the cars driving over the adjacent road surface, but the heat caused by friction to the road and the radiant heat of the engines of the vehicles is never mentioned. This additional heat might have increased the warmth of the pavement surface or increased the evaporative process, affecting the effectiveness of the pervious concrete. The cars in the parking lots might have a similar effect by providing heat that the surrounding surfaces could absorb, keeping them warmer during colder temperatures than surfaces without this variable.

This radiant heat affect could be important to my proposed research. The surface I propose would not be one that has vehicles driving or parked on it, but it would be near buildings, a possible source of radiant heat. It may be that the lack or presence of a certain level of radiant heat impacts the infiltration performance of pervious concrete in freezing temperatures, but this was not answered by any of the researchers. To consider what affect, if any, radiant heat might have, a way to measure for the presence of radiant heat and its effect or a control should be considered.

III. Proposed Research Methodology

A. Data or Evidence to be Collected

1. Description of the Data

This will be a correlational and longitudinal study from the positivist perspective (Leedy and Ormrod 183, 186).

For the pervious concrete I will collect data on the quantity of water flowing (stormwater runoff) onto, through (ground infiltration) and over the edges (containment) of the pad; and the temperatures of the air, concrete pad, adjacent building surface, and ground.

Ice from pad overflow onto surrounding surfaces will be collected for measurement.

Historical average temperatures for the months of November through February will be between 0 to 40 degrees to be a “cold weather climate.”

There will be 15-20 residential buildings per average city block. I will verify the size of the blocks, the number of houses, the lot size, and the space between houses to ensure they fit within the definition of my variables.

The rooftops will be measured for size and pitch to account for variations in stormwater flow rates and quantity differences.

2. Where the Data are Located

The surface area measurement of the roof that each downspout is connected to will be documented to determine how much water from a roof of a given size can be expected to collect in the downspout depending on the size of the storm-event.

A water meter will be placed on the roof to measure the actual quantity of storm-event precipitation at the site.

A flow meter will be installed in the downspout to measure the amount and rate of stormwater flowing from the roof and onto the pad.

A system of pipes will be installed around the outside of the pad to measure overflow.

There will be stilling wells, as used by Tyner, et al., installed under the pervious cement pads with water meters to measure the amount and rate of stormwater exfiltrating from the pad underground (130-131).

The temperature of the air, pad, untreated ground, and the surface temperature of the adjacent building exterior will be monitored, again, using sensors and dataloggers similar to those used by Tyner, et al. (2639).

Records of historical temperatures for the area for the months of November through February will be documented to confirm that the area of research falls into the "cold weather climate" definition.

B. Techniques for Collection of Data

Because this study is being approached from the positivist perspective, I will be quantifying as much data as possible to show cause and effect so that others who use my research can improve the control of stormwater events.

The roof area and pitch measurements will be taken manually and recorded at the time the water gauges are placed on top of the roofs.

Sensors measuring water quantities and flows will be automatically uploaded to remote computers as events occur.

Temperatures monitored by sensors will be recorded every minute and uploaded to remote computers.

I will visually monitor the test sites to evaluate for the presence of standing water, overflow during non-active storm events (melting snow or ice from the rooftop), and icing from runoff overflowing the pervious concrete pad. I will photograph the site if any of these are present. I will collect and quantify any ice samples.

C. Methods of Analysis

1. How the Data will be Examined for its Meaning (e.g., statistical analysis)

All samples of ice from runoff will be collected and measured; frequency and quantity will be correlated to frequency and quantity of stormwater flow from the downspout.

Measurements using a ratio scale of the quantity of stormwater runoff to the quantity of stormwater that exfiltrates from the pervious concrete pad will used to determine the feasibility of the use of this system. These measurements will be included in a report summarizing all of the data collected.

Correlations will be presented for such data as amount of actual stormwater falling to the amount exfiltrating the pervious concrete pads.

2. How the Data will be Presented (e.g., charts, essays)

I will create separate tables correlating the data for each storm event and how much water each produced to:

a) how much stormwater was captured and directed out of the downspout,
b) what percentage of stormwater that exited the downspout was captured by the pervious concrete pad and exfiltrated through to the underground pipes,
c) percentage of overflow to surrounding surfaces,
d) roof size/pitch to percent of stormwater captured by pervious concrete pad,
e) roof size and pitch to downspout flow rate,
f) flow rate to pervious concrete pad exfiltration rates,
g) temperature to downspout flow rates,
h) temperature to exfiltration, and
i) temperature to percentage of overflow of pervious concrete pad.

I will present graphs exhibiting a, b, and c; a, b, e, and f; c and i; and b and h.

Pictures of the test sites, before and during the testing will be provided.

Pictures of any icing events will be provided.

IV. Outline of the Final Report

The final report I will develop will be structured as follows:

V. Expected Outcomes

This study has the potential to make downspout disconnection acceptable to just about any property owner. The drainage/ice problem being eliminated would increase the safety of their property, reducing the likelihood of someone being injured from this slip-hazard. Once in place, pervious concrete pads do not have to be moved, drained, stored for winter or set up for summer, or maintained and repaired. Time, expense and labor should be minimal and only necessary once, at install. Minimal maintenance would be required in the form of cleaning to ensure the surface remains clear of debris. They can be compliant with Federal Law.

Architects and builders could draw upon this study in developing their designs and construction. Municipalities and engineers could apply this to stormwater management plans and best practices. Encouraging 100% residential use of this system, and, possibly, the same with commercial and industrial properties could dramatically reduce the stress on the combined sewer systems. Reduction in stress on systems should correlate to a reduction in maintenance costs for them. Neighborhood safety is increased by reduction of hazards on public walkways.

The U.S. Environmental Protection Agency might use my research in their literature and in enforcing their clean water mandates. They can show that there is a readily available, inexpensive option to assist in residential stormwater management.

The benefit of full implementation could be global. Stormwater infiltration into the ground as close to the site at which it falls is the ideal for replenishing ground water, filtering the water and reducing pollutants, and reducing or eliminating down stream flooding. Abatement of sewage overflow into waterways significantly reduces pollution.

VI.

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