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Contaminant Arresting Systems Final Report

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Submitted by

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16. Abstract

A rapid response to spills of hazardous materials on highways minimizes the consequences of such spills.

When roads with higher than average probability of hazardous material spills overlap an areas in which such a spill would be unacceptable extraordinary, preactive, efforts to minimize the effects of a hazardous spill occurring should be taken. Minimally, a real-time detection system with alarms to local responders is warranted. Maximally, a means of containing such spills within the highway drainage system, before the hazardous materials can reach the general environment should be installed.

Various methods of doing this are evaluated by imaginary insertion of the considered method into the drainage system at the site of the June 24, 2001 accident involving three trucks, 9000-gal of gasoline and a fire on I-80 in Denville, NJ. Several methods might have contained the fire and averted the major traffic delays, and the need for innovative expensive very fast-track construction.

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Table of Contents

List of Figures

Contaminant Arresting Systems

INTRODUCTION

Spills of hazardous materials on our nation's highways cost billions of dollars to clean up while creating havoc for the driving public, threatening surrounding communities, and degrading the environment. U.S. Department of Transportation Hazardous Materials Safety figures show that the number of such incidents has been increasing about 10% a year since 1992, an overall increase of almost 92% for the decade. 90% of all transportation related spills of hazardous materials in the United States occur on the highways. Nationwide direct damages from highway spills for the year 2000 were tallied at over $31billion. (1)

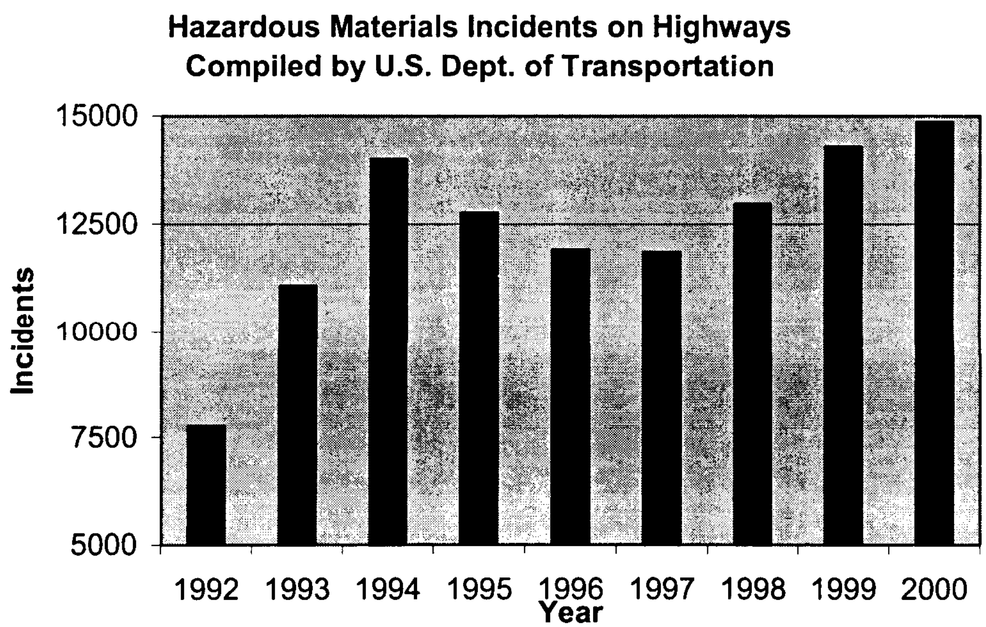


Figure 1: Hazardous materials incidents on highways

Because of New Jersey's proximity to major metropolitan areas, its intense level of industrial activity, its high population density, high per capita income and, its heavily trafficked highways, NJ has its share of this problem. In 2000 New Jersey had 384 hazardous spills on its roads costing an estimated $256 million.[(2)] An accidental spill of gasoline in Denville, NJ in June 2001 cost an estimated $34 million alone. With truck miles traveled increasing in New Jersey at a rate greater than other traffic, this trend of rising accidents involving hazardous materials can be expected to continue.

In spite of much planning to avoid them, accidents involving hazardous materials will continue to occur. Human error is implicated in 90% of the incidents. After a spill occurs little can be done about it beyond mopping-up. Inevitably, some of the spilled material will have escaped into the air, water or the ground. Almost nothing can be done about the air borne losses beyond getting out of the way while the cloud defuses. Virtually all hazardous material spilled on the ground can be dug up and removed. Liquid spills, however, are by design directed into the highway's stormwater drainage system then, on to the receiving waters. Highway drainage is designed to convey storm water off and away from the roadway as quickly as possible. Its character is the opposite of what would be desirable for containing hazardous spills. Once into the receiving waters the spilled material mires the water margins, floats away, gets dissolved and can move quickly away from the site of the spill leaving deposits all along the way. Spills of flammable liquids have been known to ignite miles away causing property damage and even death. This report emphasizes, quoting the American sage Richard Saunders, the obvious fact that the more rapidly hazardous spills are contained the less financial, social, environmental damage is done. The intent of this report is to focus on ways of preventing or mitigating water borne damage by preventing, minimizing or, at least, slowing the movement of liquid hazardous materials into the receiving waters, but some of the lessons are also directly applicable to the incidents of the other sorts as well. We argue for a preactive approach to dealing with spills of hazardous materials on highways, an approach that prepares to contain inevitable spills within the highway's stormwater drainage system, when possible, before it reaches its receiving waters. Ultimately, as Poor Richard advised us "An ounce of prevention is worth a pound of cure."

We will explore this possibility by examining what is done now regarding hazardous spills on highways, what can be done to stop them and finally, how might such systems be used. For the first part, what is done now, we will consider the legal requirements and current procedures for managing hazardous spills on highways. We will also review a survey of the fifty state DOTs and one international respondent for information and guidance. For the second part, we will examine the hardware and other engineering methods available to prevent or mitigate damage from highway spills. As a gage to the effectiveness of each of the possibilities, the various methods will be set into an actual accident situation, to consider their probable performance. What can be preactively done is to install systems to alert us, as quickly as possible, to hazardous spill incidents and, where probable incidents would have unacceptable consequences, poisoning of a large public water supply for instance, automatic systems to close-off highway drainage almost immediately so as to prevent environmental contamination would be installed.

CURRENT PROCEDURES MANAGING HAZARDOUS SPILLS ON HIGHWAYS

What is done now in the event of hazardous spills is not an accident. It is the result of four decades of environmental activism, legislation and practical experience. Manufacture, storage, transportation and use of hazardous materials is highly regulated.

Legal Requirements

Regulation of hazardous materials, generally, and spills on highways, specifically, is under the federal jurisdiction of both the Environmental Protection Agency (EPA) and the U.S. Department of Transportation established in the Code of Federal Regulations Titles 42 and 49, respectively. EPA has major authority under the Clean Water Act and several other laws as well. Appendix B to 40 C.F.R. part 355 specifically lists substances regarded as Extremely Hazardous Substances. This list includes explosives, flammables, corrosives, poisons, and biohazards to name a few other than the toxins that most people classify as hazardous materials. Threshold exposure levels are established for each substance to govern its use. All aspects of production, storage, transportation and use of these substances are regulated. The original Superfund Law and its amended version "Superfund Amendments and Reauthorization Act of 1986", SARA, form the basis for much of CFR 42.

Title 49, DOT regulations lays-out the qualifications and responsibilities of carriers and drivers hauling hazardous materials. Title 49 lists equipment, driver training and, reporting requirements. Part 397 contains rules specific to hazardous materials regarding plackarding, routing, parking and documentation.

Spills into navigable streams come under the immediate authority of the Coast Guard.

The laws for the State of New Jersey mirror the Federal statures in that spills are covered under laws administered by NJ Department of Environmental

Protection and NJ Department of Transportation. Powers of the DEP to protect the environment are laid-out in Title 13:1D-9. The Motor Vehicle laws regarding hazardous materials on New Jersey's highways are codified in Title 39:5B. Paragraph 27 establishes the Office of Hazardous Materials Transportation Compliance and Enforcement within the State police department to monitor and enforce hazardous materials laws on New Jersey's highways.

Emergency Plans

Title III of SARA, known as the Emergency Planning and Community Right-to-Know Act, section 301 requires the Governors of the States to form a State Emergency Response Commission. These subsequently form Emergency Planning Districts within the State to prepare and implement emergency plans. In the State of New Jersey there are twenty-one such districts corresponding to the counties. Each of these districts is to identify and inventory risks in their locale and, prepare a response to identified risks. Included among these risks are routes transporting hazardous materials and risk-related facilities like hospitals and schools, but to which might be added fragile ecosystems public water supplies and, potential transportation bottlenecks.

Spill clean-ups

Clean-ups of hazardous materials spills are considered to take place in two distinct phases. The objective of the first phase is to reduce the immediate danger by make people safe, particularly extinguishing of fires. Which is why, along with their trucks, fire departments tend to take the lead in responding to hazardous situations. The effected area is cordoned-off to a save distance and all unprotected people removed from within it. Next, the flow of the hazardous material will be stopped if possible, righting a bottle or closing a valve in simple cases. Then, the spill spread is slowed or stopped using pillows, booms, dikes, ditches and absorbent pads. Backhoes are useful for containing large events. The first responders, persons within the local police and fire departments specially trained and certified for these specific emergencies undertake these tasks. Regular training and reporting is mandated under SARA.

Hazardous materials specialists licensed and certified by federal, state and agencies undertake the actual cleaning-up, removal and remediation of dangerous materials. It is rare for these specialists arrive on the scene within six hours. Their job is to contain, document and remove the hazard. New Jersey contracts with several such companies all over the state to respond to hazardous materials incidents. CHEMTREX, 800-422-6237, is an industry supported EPA reporting hotline to advise responders on how to handle hazardous materials spills. Special consideration, in the form of reduced penalties, is given to transporters involved in accidents that can supply detailed information on the nature of the substance involved and measures needed in case of accident.

Survey of State Departments of Transportation

NJIT produced a questionnaire for submission through the Research Advisory Council (RAC) of which all DOTs are members. The questionnaire consisted of eight questions designed to gage interest, activity and progress of the various States in containing highway spills. The overall response to the questionnaire was as interesting for the lack of response as it was for the actual responses themselves. Of the 50 queries sent there were only seven respondents to the first submission, 14%, none for the second. This unusually low response, RAC queries usually get 80-90% response, indicates a low level of nationwide Departments of Transportation interest in this problem. Presumably, the RAC contact could think of no one to direct the questionnaire to. Or, that person failed to answer.

Questionnaire Response Summary

	1	2	3	4	5	6	7	8	%y
	Fuel Spills	Haz Spills	Ideas	Umbrella	Insight	Systems?	More	Research	
NJ	y	y	y	y	y	y	y	y	100
KS	y	y	y[1]	y[1]	y[1]	n	y[1]	n	75
NH	y	y	y[2]	n	y[3]	n	y[3]	n	63
NV	y	y	y[4]	n	y[5]	n	y[4]	n	63
MT	y	y	y[4]	n	y[6]	y[4]	y[7]	n	75
CT	y	y	y	y[8]	y[6]	y[9]	y[1]	n	88
FL	y	y	y[10]	y[10]	y[11]	y[12]	n	n	75
%y	100	100	100	57	100	57	86	14	
UK	Y	y	y	y	y	y	y	y	100

1 Staged materials

2 Better communications and coordination between police, fire, Haz-Mat and DOT

3 Install booms and separators in sensitive areas near ROW

4 Spills cause traffic hazards

5 Use detention structures to prevent flow directly into receiving waters

6 Need fast but safe response

7 Hazardous exposures, clean-up costs, product loss, environmental damage, roadway damage, traveling delays

8 Accident prevention

9 Maps of drainages

10 Mats and booms

11 Dam gutters and ditches

12 Pay attention to groundwater

13 Vacuum trucks

Table 1: Questionnaire Response Summary

1. Does your state have any means of arresting spills of gasoline, diesel fuel or heating oil on your highways?
2. **Does your state have any means of arresting spills of hazardous materials on your roadways?**

Respondents tended to regard questions 1 and 2 as the same but they were intended to differentiate whether or not common automotive associated spills like gasoline, diesel fuel or engine oil might be handled differently than other hazardous materials. It was also intended to look for automatic detection and response systems rather than the emergency services one that seems to be generally in place. In terms of automatic response, all answered negative. However, knowing everyone is doing all they can and not wishing to say that the States are doing nothing to manage spills of hazardous materials on highways I recorded positive response.

3. **Do you have any ideas on ways of containing highway spills within the highway drainage, before it escapes into receiving waters and the general environment?**

Virtually all respondents described pillows, booms and other kinds of absorbents. Ditching, damming and otherwise impeding liquid flows was also often mentioned. One respondent stressed the importance of coordination between different agencies while dealing with a situation.

Two respondents suggested using stormwater detention systems as a means of arresting spills on highways before the spill reached receiving waters.

One respondent stressed the need for proper communications between different agencies involved in responding to major spills.

4. **Do you have any ideas on ways of containing highway spills that include the umbrella section of the road?**

No preactive ideas here. Any response tended to describe manual methods like ditching, damming and absorbing.

5. **Can you provide any insight into the problems created by highway spills?**

Traffic delays, product loss and, the need for a prompt response were multiply mentioned. UK respondent reminds us that any organic material, milk, sugar or alcohol could have devastating effects on a receiving water. Florida respondent points out the vulnerability of ground water.

6. **Have you ever heard of any systems for containing spills on highways?**

Again, there was no mention of automatic systems. Accident prevention came up here. A Vacuum truck was suggested as a useful type of response vehicle.

7. **Do you believe that any measures beyond what is currently done to control highway spills are required?**

There were several good suggestions here. Choreographed action on the part of responding agencies to minimize turf wars during an event was recommended. Problems of just this sort are known to have occurred during a fire adjacent to the New Jersey Turnpike several years ago.

A need for access to good drainage maps by first responders was also suggested.

8. Is anyone doing, or has anyone in your state done, any research on containing highway spills?

For all respondents this question 100% negative. No one, other than the author of this report, can be identified as having researched automatic ways of containing highway spills of hazardous materials within the highway storm drainage system.

June 22, 2001 I-80 Denville Accident & Fire

On June 22, 2001, at the beginning of the morning rush, a gasoline tanker truck overturned on I-80 just before Exit 39 in Denville, NJ, spilling its 9000-gallon load of gasoline onto the highway. A fire ensued which ignited which destroyed the tanker and two other trucks. Additionally, and more significantly, burning gasoline flowed through the highway drainage into the Denn Brook, flowing under bridge, where it continued to burn, destroying the bridge as well. For several hours flames engulfed the 52-ft. wide, 49 ft.-long skewed prestressed concrete bridge. The fire, confined under the bridge, reached six fifty odd foot long, AASHTO type 4 beams which were blackened and spalled, the prestressing tendons were exposed and had been ruined by fire temperatures in excess of 1500°F. Westbound traffic was completely closed for ten days while a temporary two-lane bridge was installed at a cost of $10 million. A Fast-track replacement bridge took three months to build at a cost of $20 million disrupting traffic for months. Estimated user costs were in the neighborhood of $35 million. The cost and level of disruption to the driving public argues for an expanded notion of what constitutes a sensitive area.

The accident is illustrative and will be used as the basis for a case study examining each of the identified technologies for prevention or mitigation of hazardous spills on highways. It is quite exemplarily in that the majority of hazmat spills involve flammable liquids. It took place along an interstate highway with typical drainage system. The local was lightly urbanized with good emergency services. Each device will be imagined to be in place in proper operating order in the drainage system for the bridge over the Denn Brook at the time of the accident on June 22. Its possible impact on the outcome accident will be considered.

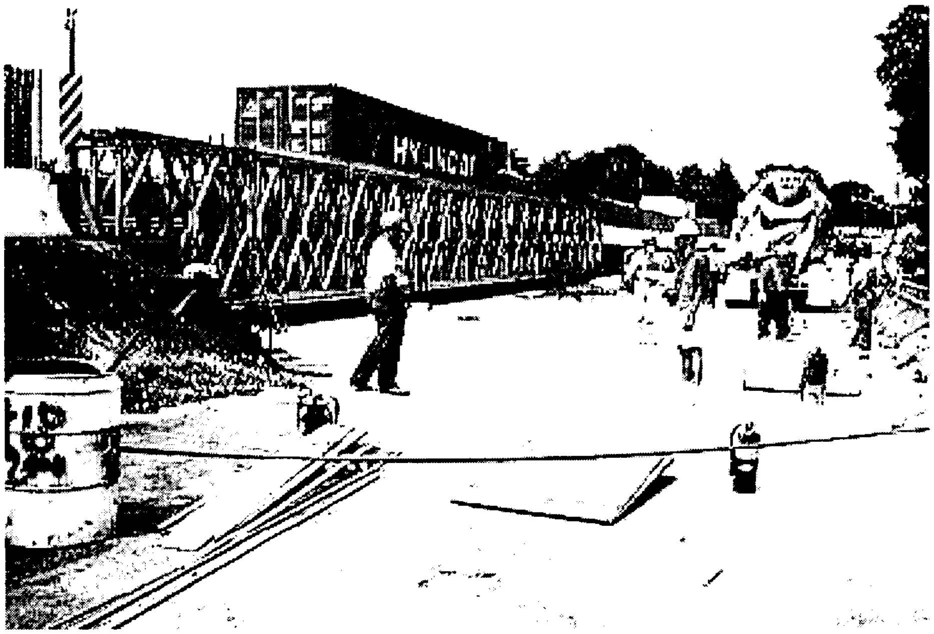


Figure 2: Temporary I-80 bridge and construction

METHODS FOR INTERCEPTING HIGHWAY SPILLS

Using existing technologies quite a lot could be done to intercept spills of hazardous materials before they enter the receiving waters. The technology for closing off fluid flows through pipes is not new. Some exciting new technologies exist, however.

Existing Technology

Accident Return Periods in Sensitive Areas

Whatever type of detaining system is used it is always useful to expend resources in areas where maximal effect is likely to be achieved. Some stretches of highway that carry hazardous materials traverse particularly sensitive areas. These are areas where hazardous spills would be unacceptable for environmental, strategic or other social reasons. Other stretches of road, due a variety of factors, are more prone to accidents. They might be particularly narrow, have limited site distance, be in a foggy area or on a tight curve. When these zones correspond, accident prone, sensitive areas where contamination would be unacceptable special efforts need be made before an accident occurs. Identifying such areas will be key to using spill mitigation strategies with maximal effect. For identifying sensitive areas one will need to consult the local emergency planning. For identifying areas with increased accident potential, a technique suggested by the British Highway Agency offered promise.

The British Highway Agency in its UK Design Manual for Roads and Bridges [(4)] suggests the following equation to determine the probability of an accident involving a hazardous spill over a section of the roadway.

$$P_{acc} = RLxSSx(AADTx365x10^{-6})x(\%HGV \div 100)$$

Where:
P_{acc}= Probability of a serious accidental spillage in one year over a given road length
RL = Road Length in Kilometers
SS = Serious Spillage rates from Table 3.2 (or local data if available)
AADT =Annual Average Daily Traffic
% HGV = Percentage of Heavy Goods Vehicles

This equation calculates the average return period for hazardous spills involving heavy goods vehicles, trucks, per year. The serious spillage rate divides the number of accidents over a given period of time within a defined district, a state for instance, by the number of vehicle kilometers driven within that district for that time period. It has the advantage that it makes the probability of accident proportional to both the length of the stretch of highway in question and the number of vehicles using that stretch of road.

Other means of predicting the probability of an accident can be developed using local accident records which, by restricting considerations to just accidents occurring along a particular stretch of road given a measurable amount of traffic. The author believes local responders can identify areas where accidents are more frequent. Selection of a site for funding and application of a drainage closure system can follow essentially the same methods used for justifying traffic lights.

Storm Drain Filters

Several companies make storm drain filters. In one way or another a filter element is arranged in the inlet of the drain such that all flow passes through the filter. These devices are meant to capture particulates and oily films before stormwater reaches its receiving waters. It is intended that these would be replaced regularly as it is expected they will fill with particles and oily residuals.

These systems are designed to deal with an environmental problem related to highway spills. This is the much greater problem of non-point pollution. As a result of the environmental clean up that started in the 1970s, virtually all of the large point sources of pollution have been identified and regulated. Today, the largest contribution to the pollution burden comes from non-point sources. Particulates, phosphorus, nitrogen and insecticides, the worst ones, from a water environment point of view, of these non-point pollutants, reach the water supply via farm operations and applications, for example. In 1996 the GAO estimated 46 million gallons of oil, the equivalent of more than four Exxon Valdez disasters, is spilled, dumped, drips or otherwise is washed into the nation's lakes, streams, rivers and oceans. [5] Half of these were spills during loading and unloading operations. If used widely and properly these low-tech filters systems could reduce non-point source pollution significantly.

However, for the case of interest to us, that of hazardous spills on highways, drain filters would help in only the smallest cases. Anything exceeding the absorptive capacity of the filter, a quart of oil perhaps, would run through the filter. If such a system had been present in Denville, it would have made no difference to the outcome. It would have soaked-up gasoline to its capacity but, hundreds of gallons of gas would have just flowed through the filter. It is not impossible that the filter might have separated the fire on the road from the drains but, in all likelihood, even if this were the case, eventually the filter would have been burned up itself and the fire would have worked its way under the bridge to do its worst.

Oil/Water Separators

Half of the oil spilled every year comes in the form of spills occurring during transfer operations.[5]

There are two general types of oil/water separators, a baffled type and a coalescing type. Through a clever combination of baffles and underflows a tank can be divided up in such a way as to separate oil from water. Coalescing is done by slowing flow enough to permit small amounts of oil to coalesce and float to the top of a chamber.

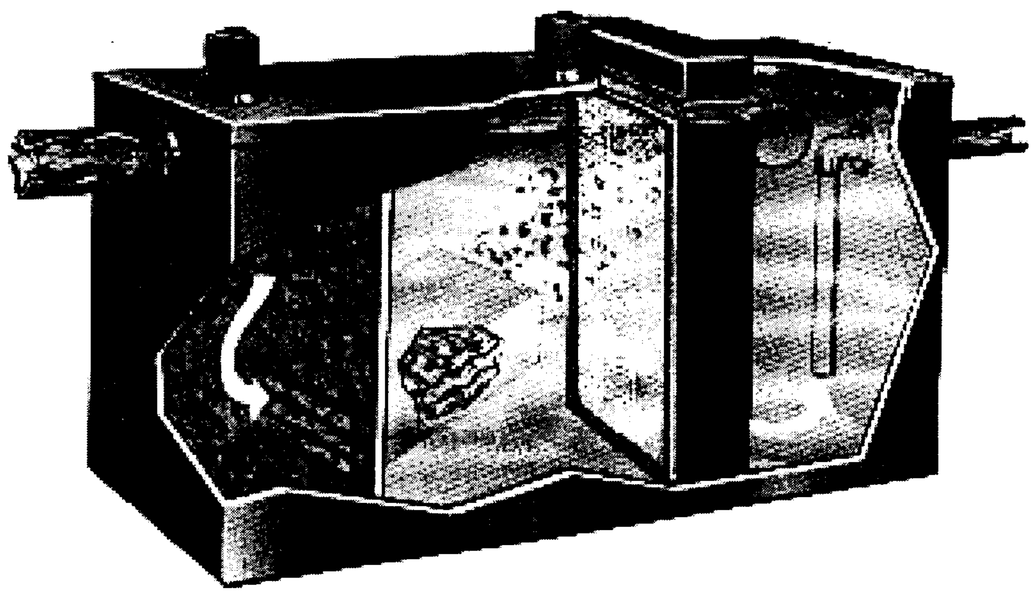


Figure 3: Combination Baffled and Coalescing Oil Water Separator
(Courtesy McTighe Oil Water Separators)

Swirl or Vortex Concentrators

Much of the damage of non-point source pollution is in the form of sand and silt. These are the natural products of erosion, hastened along by human activities. These little particles silt-up lakes and streams, reducing their carrying capacity and storage volume. What drain filters do on the small scale the swirl concentrators do on a larger scale. Through clever arrangement of baffles and jets a vortex is caused to form in a chamber. The relatively slower speed of the water in the middle of the whirlpool allows suspended solids to settle out from where they can be recovered later.

For both the oil water separators and the vortex concentrators several hundred gallons or more, depending on the exact configuration, are held during operation. On Route 80 that day, had these been in place they would have captured a few hundred gallons within them limiting the amount of gasoline released into the stream under the bridge but enough would probably have gotten through to cause significant damage to the bridge in the end.

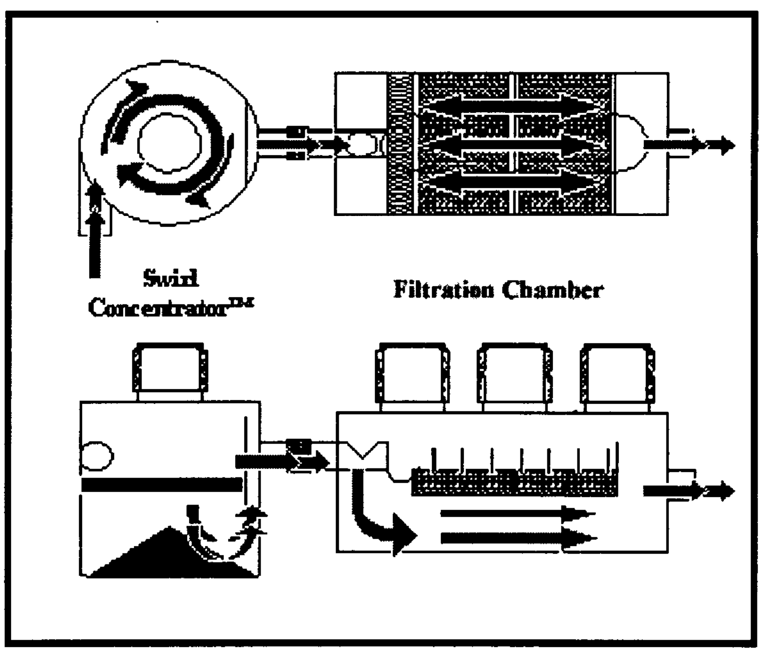


Figure 4: Schematic of Swirl Concentrator

Flow Balancing and Underwater Detention

Flow balancing is a clever technique developed in Sweden by Karl Dunkers in the 1970s that uses part of the volume of a large stream, a lake or the ocean as a stormwater detention tank. The flow balancing tank is formed from plastic sheets attached to floating platforms and anchored to the bottom. It is successfully used at Fresh Creek in Brooklyn, New York City to manage combined sewer overflows, CSOs. CSOs tend to occur in old city sewers where sanitary and stormwater sewers are combined. In the event of an extremely large storm event the carrying capacity of the sewer pipes is exceeded. The polluted excess flow is discharged without treatment directly into the receiving water. The combined sewer overflows. The flow balancing detention system is able to catch and hold the overflow for later treatment. When the flow through the system has fallen to the level where it can conveniently be accepted the CSO is pumped back into the system and conveyed to the treatment plant. Fresh Creek Technologies of Cedar Grove, New Jersey designs and installs these systems in the United States.

When an overflow or, for our purposes a spill event, occurs in a place like Fresh Creek, or the Jersey shore, it enters the top surface of a salt water tank, because its is less dense than the salt water, and displaces salt water down and out through a control opening at the bottom of the curtain. In salt water, a boundary layer is formed between the lighter, polluted overflow and the denser saltwater. Experience has shown that the boundary layer remains intact over time. When the overflow has stopped and the wastewater plant is operating at less than maximum flow rate, the polluted water is pumped from the surface of the tank to the plant for treatment. Spilled hazardous materials would be similarly pumped out. While the CSO is stored in the EquiFlow System, some settling of solids occurs which must be periodically removed. In fresh water, there is no boundary layer. To isolate the polluted water from the clean water, intermediate pontoons and curtains are installed to form a series of compartments. This configuration produces a "plug flow" effect as the overflow fills the intermediate tanks in series through the curtain openings. [(6)]

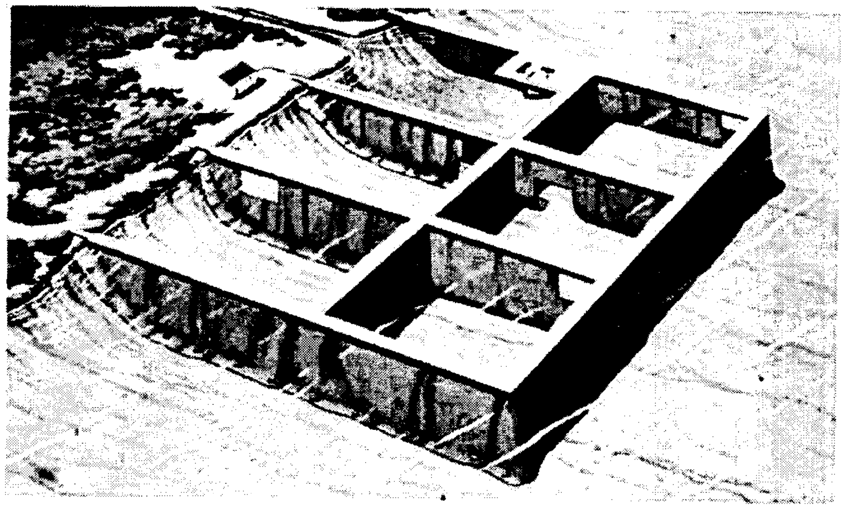


Figure 5: Flow balancing system schematic
(Courtesy Fresh Creek Technologies)

Had such a system been in place for the I-80 accident, the flow would have been directed to a flow balancing tank. By sending the spill there it would have been concentrated away from the bridge, perhaps. As the "tank" baffles are floating plastic sheets, it is probable that a fire would have burned the floats and sheets, the spill would be released and the fire could spread across a whole lake unless secondarily contained. The whole body of water would have been contaminated with gasoline as though it weren't there at all. There would have been some time during which the fire might have been extinguished and the contamination held. In a case where there was no fire, almost all the floating product could be recovered. Dissolved substances would be slowed from entering the rest of the body of water. If not pumped out within several days the whole contamination load could eventually dissolve into whatever body of water.

Underwater detention, like flow balancing uses some of the volume of the receiving water for stormwater detention. For underwater storage the containment is in a large bag suspended in the water. Fresh Creek Technologies also designs and installs these systems. An underwater storage system would have been able to contain this spill well. The absence of air would have meant that nothing could burn. The containment would have had to been perfect though since the gasoline in this case, being lighter than water would want very much to float away.

The Denn Brook is not a large body of water, neither of these systems would have the necessary storage volume to manage this site.

Environmentally Engineered Storm Detention

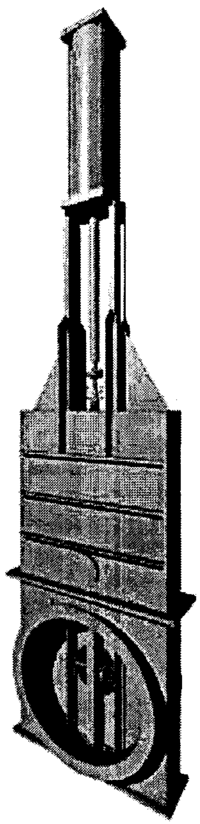
Environmentally engineered storm water detention differs only in the final details from traditional design of detention basins. Standard basins are designed to capture the stormwater flow of the contributing area, releasing it no faster than the rate that matches the flow to the receiving waters before development. These traditional designs also reduce the amount of particulates reaching the streams by settling them out in the detention basin. Some of the oily films would also be adsorbed onto the grasses and other plants within the detention basin, reducing the release of these pollutants as well. This petroleum hydrocarbon pollution is food for some types of bacteria. Getting these bacteria ready to gobble-up pollution is the business of bioremediation.

Environmentally engineered detentions would enhance the ability of the native flora and fauna to resist and degrade potential pollutants. Bioremediation uses naturally occurring microorganisms, when available, to convert harmful substances, like petroleum hydrocarbons, to harmless ones like carbon dioxide and water. Bioaugmentation and biostimulation are the tools of bioremediation. Bioaugmentation introduces bacteria that specialize in processing a particular substance that may not be locally present. Biostimulation encourages the growth of the domesticated bacteria by providing them with the nutrients they need which naturally tend to limit their activity. These nutrients are typically exactly fertilizer, nitrogen and phosphorous most commonly, but other substances might need to be supplied in specific cases.

Environmentally engineered detention basins would bioaugment the area under the pond with bacteria specialized for the target material. In the case of petroleum hydrocarbons, the critters would subsist on the background pollution, also referred to as non-point source petroleum pollution adding up to a few Exxon Valdezs a year. In the case that a spill would end-up in this basin, after any standing liquid had been pumped-out and the contaminated mud and muck removed it would be biostimulated with fertilizers and anything else needed to be sure that growth would only be limited by the hydrocarbon source.

Had such a system been present in Denville, the damage would probably have been as minimal as possible. The gasoline would have been conveyed to the detention basin where it would not have reached the level to have started to drain out. Even if it had started to escape, the flow would have been slowed. The fire would have burned in the basin adjacent to or somewhat away from the highway proper. No fire would have gotten under the bridge to damage it. Traffic tie-ups would have been limited to the time needed to extinguish the fire.

Valves



66-inch Gate Valve
(Courtesy Deltavalve™)

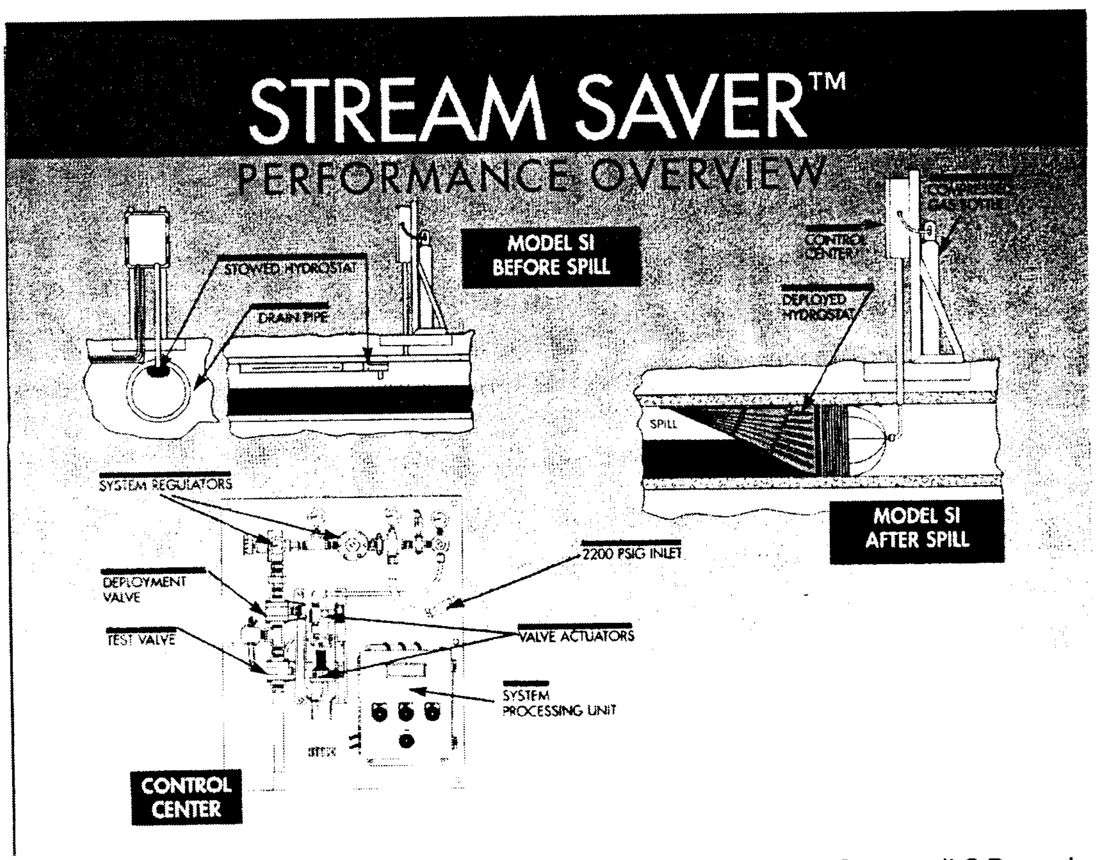
Valves are the standard method for stopping the flow of fluids through pipes. The pipes in highway stormwater systems are relatively large as pipes go. Sizes start around 8-inches and go up to 66-inches, possibly larger in some special situations. Additionally, all manner of stuff flows into stormwater drains, dirt, sticks papers, anything that ends up on the street can end up in the storm drains. The only type of valve that makes sense in such conditions is a gate valve.

The valve can be manually or automatically actuated. Big valves need a lot of cranking to close them off and in an emergency situation time is of the essence, so automatic actuation would be the likely candidate. Pneumatic actuation using compressed gas is common in industrial applications and would probably be used for this application as well. Heavy springs can also be considered.

Had this kind of system been in place and operating as envisioned for the accident of June 22 the fire would have been confined to the highway. Firemen interviewed reported that a big fire was preferable to lots of little fires popping up all around. In this case the firemen would have been able smother this fire under foam.

Stream Saver

The Stream Saver was a little noticed great idea from the ILC Dover Co., better known for their spacesuits. It found a little application in transfer facilities and tank farms. Several were installed at Air Force facilities. It was an inflatable plug, shown in figure 5, which, when activated could stop the flow of stormwater, running full, through a 48-in. pipe under 20-ft. head. In its most advanced configuration it would be slipped into a pipe at the inlets. Sensors in the inlet would be monitored by a controller which, when conditions warranted, would inflate the Stream Saver by activating the valve to a bottle of nitrogen gas. It would also send an alarm to the appropriate responders. All Stream Savers installations, there are a few, are manually activated, someone has to push a button. In 1997, due to an almost complete lack of interest the product the company closed down its Stream Saver operation. Talking to them for this report I was told that they would happily reconsider producing the product again, if demand were to call for it.



Courtesy ILC Dover, Inc

Figure 5: Stream Saver Schematic

Interface with intelligent transport systems

Intelligent transportation systems (ITS) seek to apply sensors, computers and feedbacks of various sorts to increase the safety and capacity of highways. Sensors currently in use include closed circuit television, inductive wire loops, and piezoelectric crystals. In the most ambitious concepts, drivers relinquish control of their automobile to the highway. Higher speeds and closer following distances will increase the highway capacity while computer control makes the whole system safer and nothing can go wrong go wrong. After linking into the roadway network, vehicles are located and controlled by the computer network that feeds-back entry and exit, speed and distances commands. Exiting and unlinking from the system would be preprogrammed. Have your credit card ready. In the event of an incident effecting flow traffic, a roadside building fire for example, the computer would shunt traffic off and on the highway and facilitate movement of emergency equipment.

All we would do is monitor hazardous materials sensors in critical areas as well. The ITS system would detect an event. It would immediately respond to it by activating a system of valves or a Stream Saver perhaps, preventing further spread of the offending material. Local first responders would be alerted as to what kind of situation had occurred and where it had happened. Perhaps they could view it on television. The ITS would redirect traffic away from the incident, clearing the way so the fire trucks can get there as quickly as possible.

Had a system of valves or a Stream Saver perhaps, sensored for hydrocarbons, and/or fire, been operational in Denville on June 27 within and under the control of an ITS system programmed for spills of hazardous materials the goals of this report would have been realized.

Proposed Technology

Fiber optic technology to detect spills on umbrella section

Spills of hazardous materials onto the umbrella section of the highway are particularly problematic. The umbrella section is that part of the highway where the shoulder meets the grass, there are no curbs or drains, contributions of precipitation from the road simply flow off into the woods, wetlands or wherever. There is no possibility of containment on the highway until emergency services arrive and generally, there is no stormwater detention system. Early detection, then, is the next best thing. Fiber optic sensors, sensitized for the most common or expected spills, could be developed and deployed for miles along the roadway to detect spills. The fiber, or fibers could, be woven into a geosynthetic fabric that would aid installation and additionally serve to stabilize the slope.

In the event of a spill, a fiberoptic sensor, part of a much larger monitoring system, would indicate an alarm condition to the monitoring station. The monitoring station would send this alarm to a central station that would dispatch appropriate response.

Satellite relay of sensor detection

Drainage invert or far-flung fiberoptic sensor networks would normally be connected to central monitoring stations using normal telephone technology, either hardwire or cellular. However, there are vast areas where neither standard method has service. For such areas, another concept we have developed is that when an event is detected in extremely an isolated area an alarm message would be sent to an orbiting satellite that would in turn relay the alarm to a ground station that would dispatch the nearest local emergency responders.

A spill of hazardous material onto a highway would be detected by either a system in the drainage or a fiberoptic cable. This detection would create a particular alarm condition on a given node which would be relayed either by telephone or satellite to a central monitoring station. The central monitoring station would alert local emergency services that would dispatch appropriate response.

A STITCH IN TIME

All things that can prevent accidents from occurring should be done. All manner of training and testing, reporting, signage, warnings of whatever kind should be applied to prevent accidents from happening. However, in spite of best efforts, it can still be expected that accidents will occurre.

If accidents can not be prevented, immediate detection and rapid response are the next best things. Two things determine the potential damage done by a spill. The first is how much damage was done to the container during the accident, in other words, how big the leak is. The second thing is how quickly emergency response can be on the scene and how quickly they can control the spill. For the first part continued research on container safety needs continue. For the second part, emergency services need to be properly equipped and trained. Beyond these are the recommendations and suggestions of this report. We have shown that it is possible to install various technologies that could actively or passively stop or detain spills of hazardous materials on the highways. It is envisioned that these installations would be an exception rather than a rule, being installed in areas where accidents are unacceptable.

Some places are more accident prone than others. If these areas can be identified and if it coincides with an area particularly sensitive for environmental, general public well being or, other reasons making spills there unacceptable, than extraordinary, preactive efforts are called for to protect the environment and public well being. Installing drainage protection systems into sensitive areas would be the proverbial stitch in time. The costs of installing systems now can reduce or prevent the greater costs of often hasty imperfect clean-ups later.

In some cases two benefits can be had from one installation. General, widespread installation of non-point source pollution controls, like storm drain filters or oil water separators, could further a general environmental clean-up and at the same time serve to mitigate to some extent extreme events like spills of hazardous materials on highways.

CAUTION

One of the biggest problems with technology is that it is not perfect. In our evaluation of the various methods by which the environment might be protected in the event of a hazardous materials spills onto highways it was assumed that the devices were properly installed and working perfectly. Since operational perfection is rarely possible good maintenance and testing, with atomic bomb like attention should be attempted. System failure scenarios need be considered in the design.

A bigger problem comes from the other direction. What happens in the case the drainage is closed-off? We are considering, in the case of a spill, to have a puddle of liquid several inches deep and a few hundred feet square. What would be the consequences of a vehicle hitting that puddle? At least additional signage is needed to stop traffic if a drainage system is closed. Accidental activations would leave valves closed and drainage stopped. In the event of a storm the highway would flood. Legal responsibility for creating such a puddle on the highway, perhaps for an ensuing fire within or who knows what, needs be considered. This potential hazard is to be balanced against the protection to public welfare coming from restricting the spread of hazardous materials into the environment.

CONCLUSIONS ON CONTAINING HIGHWAY SPILLS

1. Survey of States and internet search finds no current activity on automated closure of highway drainage.
2. Response to hazardous materials incidents needs some level of pre-coordination to minimize or avoid authority clashes during incidents.
3. Equations for predicting hazardous materials spills need to be further developed and perfected.
4. Use of non-point pollution prevention devices, like drain filters and oil water separators, will contain small to moderate sized spills and, if used widely would contribute another increment of improvement to the quality of receiving waters.
5. Stormwater detention basins can be environmentally engineered to capture and hold and, to a limited extent even treat, spills of hazardous materials on highways.
6. Means of detecting spills of the most common hazardous materials spilled on highways are available.
7. An innovative means for emergency reporting of spills of hazardous materials, using fiber optic technology, on umbrella section of highway is suggested.
8. An innovative means for emergency reporting of spills of hazardous materials in remote areas using satellite relay technology is suggested.
9. Hazard specific alarms signaling hazardous spills can be sent to local responders either as part of an Intelligent Transportation Systems or as a stand-alone system.
10. Various conventional and innovative means for closing-off highway drains are available.
11. Accident-prone areas can be identified.
12. Areas where spills are deemed unacceptable can be identified.
13. In accident-prone areas where spills would be unacceptable preactive measures to prevent or inhibit flow of hazardous materials from the highway, by containing as much as possible of it within the highway drainage system, are warranted.
14. Legal consideration of the inadvertent creation of a highway danger, created by temporally stopping highway drainage needs consideration by competent legal authority.

APPENDIX

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