Plastic Culverts in Fire-Prone Areas: Survey of State Practice

Requested by
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Table of Contents

Executive Summary

Background

The 2018 wildfires in California prompted Caltrans to investigate vulnerabilities and possible solutions that may protect plastic pipes and culverts during wildfire events. Caltrans may use plastic in culverts in two situations:

- Designing and placing new plastic culverts.
- Rehabilitating existing culverts in the field with plastic pipe liners.

Caltrans' Highway Design Manual discourages the use of plastic pipe and bituminous or plastic coatings in fire hazard areas due to potential burning or melting and recommends consideration of nonflammable materials or modification of the plastic pipe in situations where high fire potential conditions exist for cross culverts. An analysis of Caltrans' inventory of inspected culverts that are made of high-density polyethylene (HDPE) and polyvinyl chloride (PVC) in conjunction with fire hazard severity zones indicates that almost 850 out of a total 18,160 culverts have a high probability of vulnerability to fire in zones classified by California Department of Forestry and Fire Protection (CAL FIRE) as moderate, high or very high fire hazard areas.

Caltrans is interested in learning about the practices and products that can help protect plastic culverts from being damaged during and as a result of wildfires. To assist with this information-gathering effort, CTC & Associates summarized the results of a brief email survey of state departments of transportation (DOTs) that gathered information about other agencies' practices and experience with plastic pipes and culverts. Findings from a literature search supplemented survey results.

Summary of Findings

Survey of Practice

An email survey of members of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee Listserv, which includes participants from all 50 state DOTs, sought information about agency policies, procedures, specifications or guidelines for the selection and application of pipe and culvert materials, generally and in fire-prone areas. Twenty-nine agencies responded to the survey.

<u>Selection of Culvert and Pipe Materials</u>

Respondents took different approaches to responding to a request for agency policies, procedures or practices associated with the selection of culvert and pipe materials. Some provided only a link or reference to a publication, while others offered a brief description of agency practices. A small group of respondents simply acknowledged that their agencies had such specifications but offered no details about them. A table summarizing agency practices, when provided, begins on page 13. Publications provided or referenced by respondents are cited in **Related Resources** beginning on page 18.

Use of Plastic Culverts in Fire-Prone Areas

Six respondents described agency policies or practices that address the placement of plastic culverts in fire-prone areas. None of the respondents described practices specifically designed to respond to the threat of wildfires.

- Colorado DOT exercises caution in using plastic culvert pipes in agricultural areas where ditches are burned seasonally to clean out old vegetation.
- Minnesota DOT issued an April 2017 Technical Memorandum that provides guidance on consideration of fire risk, advising against the use of plastic pipe "where there is a likelihood of exposure to fire without fire mitigation."
- While Montana DOT's policies do not specifically address fire-prone areas, the agency does consider fire risk in connection with ditch burning, a common practice in Montana to clean irrigation ditches and pipes.
- Nevada DOT does not allow the placement of plastic pipes under travel lanes of high-volume roadways in the event of a pipe failure due to fire. However, plastic pipe is allowed under shoulder sections where a failure wouldn't close the road.
- In North Dakota, the primary fire concern arises from landowners with property adjacent to the highway who opt to burn ditches to control vegetation. Typically, the DOT does not allow plastic pipe under the mainline in these areas.
- Oregon DOT does not use plastic pipes when the agency is aware of a fire concern. The respondent did not cite a specific policy or guidance document that codifies this practice.

Protecting Plastic Culvert Inlets

The table below summarizes agency practices to protect plastic culvert inlets.

Agency Practices to Protect Plastic Culvert Inlets

State	Practice
Colorado	The agency requires the use of metal end sections at the ends of plastic pipes. While this modification was not specifically intended to protect plastic pipes from burning, it does have that effect.
Florida	Agency policy is to not use unprotected plastic pipe on drainage end sections to prevent deterioration due to UV exposure and exposure to heat and fire.
Georgia	Standard 1030P, Thermoplastic Pipe (revised September 2016), indicates the requirements for concrete or metal end sections for both ends of thermoplastic pipes.
Illinois	Agency guidance requires that for "all pipe culverts, with the exception of entrance culverts, a nonplastic end treatment must be specified. An end treatment for entrance culverts, which can protect the culvert ends from being crushed and allow for proper grading of the transverse slopes, will be at the designers' option."

Agency Practices to Protect Plastic Culvert Inlets	
State	**Practice**
Minnesota	Agency guidance recommends not using plastic pipe where there is a likelihood of exposure to fire without fire mitigation alternatives, which include concrete slope paving, concrete headwall and concrete aprons.
Mississippi	Agency guidance requires that all pipe materials other than concrete have a concrete end section.
Montana	While agency policies do not specifically address fire-prone areas, if the agency is concerned about the possibility of ditch burning, a concrete headwall or other concrete end section would be included in the culvert design.
Nevada	Unspecified other agencies place a plastic pipe under a roadway that substitutes corrugated metal pipe (CMP) or reinforced concrete pipe (RCP) for the last segment of pipe on either side. This practice is expected to decrease the likelihood that a fire could compromise the plastic pipe and, in turn, the roadway.
North Dakota	For approaches, the agency typically requires the application of a nonflammable segment on the ends of each plastic pipe.
Oklahoma	An agency special provision for plastic pipe mandates a concrete end section of plastic pipe in all installations, regardless of location.

Research or Practices Related to Fire Protection

Only the Florida DOT respondent reported on research that sought to examine fire protection for culverts, noting that the agency performed a flammability study on HDPE drainage pipe “several years ago,” and the results supported the agency’s policy to not use unprotected plastic pipe on drainage end sections to prevent deterioration due to UV exposure and exposure to heat and fire. The respondent also noted that “[f]lammability is more of a concern on pipe ends since oxygen limitation would prevent flame spread inwards.”

While the respondent did not provide further details of this study, the literature search that supplemented this project’s survey findings and an email response from Florida DOT identified repeated references to a July 1994 Florida DOT study, High Density Polyethylene Pipe Fire Risk Evaluation (see Attachment C). The July 1994 report includes the following on page 1 of the report (page 7 of the PDF):

> At present, HDPE may be used in diameters up to 0.91 meters (36”). Approved applications are for cross drains, edge drains, underdrains, gutter drains and side drains. In all applications the pipe ends must terminate in either a concrete headwall, drainage structure or non-plastic mitered end section with a concrete apron.

Based on the field burn tests, where concrete headwall and metered end section were used with different combinations of vegetation density, the report’s conclusions, which begin on page 16 of the report (page 22 of the PDF), indicate that “[p]olyethylene pipe installed to present FDOT standards is not at significant risk of fire when exposed to expected grass fire intensities” and “[i]n the event of an actual in-pipe fire, the burn rate is expected to be very low (0.0085 m/minutes) or (1.7 ft./h).” Laboratory tests showed that the flash point of polyethylene pipe and asphalt pipe coating was 740°F and 595°F, respectively; the burn point of these materials was 750°F and 620°F, respectively.

A summary of the nationwide survey conducted for the July 1994 Florida DOT study indicated that “[o]ut of 41 states reporting, only four reported incidents of fire and the total reported number of fires was eight.” Survey results also indicated that “the computed rate at which fires have occurred is one fire per state every 48 years” (see page 14 of the report; page 20 of the PDF). The report’s assessment of fire risk noted that “[b]ased on the results of this study, the overall risk of fire to polyethylene pipe is considered minimal” (see page 15 of the report; page 21 of the PDF).

Related Research and Other Resources

An expansive search of domestic and international resources sought information about the practices and products that could be used in connection with plastic culverts in fire-prone areas. The literature search extended beyond recently published resources to consider publications dating back to the 1980s and sought information about the use of plastic in applications other than transportation infrastructure that might be relevant to Caltrans’ interests. The search identified relatively little in the literature that goes beyond echoing or recommending Caltrans’ current practices to consider alternatives to plastic in fire-prone areas and modifications of plastic culverts to protect them from fire.

Highlighted below are key findings from the literature search. Refer to the **Detailed Findings** section of this report for further details of the publications described below and additional citations.

National Guidance

A 2015 National Cooperative Highway Research Program (NCHRP) synthesis report on the service life of culverts commented briefly on fire risk and fire damage associated with culverts, noting that “[a]lthough the risk of damage to storm drainage systems is quite low, under certain circumstances, such as forest fires, damage to culverts can occur. In forest fires, all pipe material types can sustain damage from exposure to extremely high temperatures. While thermoplastic pipes would be the most vulnerable, the National Fire Protection Association (NFPA 2012) has given both polyethylene and polypropylene a rating of 1 (Slow Burning) on a scale of 0 to 4, where higher ratings indicate a greater vulnerability.” A 2012 Forest Service publication also highlighted the agency’s recommendation to use concrete or masonry headwalls for flammable plastic culverts and liners in forest environments where fire is a possibility.

A 1980 NCHRP report provides a historical perspective on the treatment of plastic pipe to reduce its vulnerability to fire, including this recommendation:

> Plastic pipe should be terminated underground, and noncombustible pipe should be installed from this terminus to areas that may be exposed to [grass and brush fires] or other accidental fires.

Other Agency Guidance, Practices and Experience

Canadian publications that address fire resistance include the 2007 Ministry of Transportation of Ontario pipe design guidelines and a 1998 literature review. Both publications consider the temperatures at which plastic pipe deforms. California’s experience with plastic culverts in fire-prone areas is addressed in a 2007 task force report describing the impacts to the Santa Margarita River/Sandia Canyon and Lower Murrieta Creek from the 2007 Rosa Fire in Riverside County.

Other state DOT publications address the impact of fire on plastic culverts:

- A July 1991 Colorado DOT study describes the replacement of corroded metal pipes with corrugated polyethylene pipes and a subsequent fire that impacted one of the replaced culverts.
- A 1996 Iowa DOT research report includes an investigation of the flammability of HDPE pipe used in highway applications. The report cites the results of related studies by Phillips Chemical Company and North Carolina DOT's Materials and Tests Unit:
    - Phillips Chemical Company concluded that testing according to ASTM D635 and MVSS 302 classifies polyethylene as burning at a rate of 1 inch per minute. The flash temperature was 645°F with a self-ignition temperature of 660°F, and the minimum concentration of oxygen that will just support combustion is 17.4 percent.
    - In a flammability test conducted by North Carolina DOT, the double layer design of a pipe caused a fire to be constantly fueled throughout the length of the pipe. The pipe burned at an approximate rate of 1 foot per 20 minutes.
- A 1998 South Dakota DOT report that evaluated HDPE pipe also considered the potential for damage by fire. South Dakota DOT uses an Approach Pipe Plan Note specifying that Class II RCP with safety ends and polyethylene pipe with CMP end sections may be substituted for CMP at approaches on a per site basis. The end sections for the polyethylene pipe must be metal, must conform to the details for CMP end sections and must be compatible to the polyethylene pipe.
- Texas DOT practices are described in a 2018 pipe selection procedure and the agency's response to a 2017 AASHTO Committee on Construction survey that examined the use of polypropylene pipe for cross drains and side drains. In responding to the 2017 survey, a Texas DOT respondent reported on an agency practice to protect the ends of polypropylene pipe installed under a paved roadway with a nonflammable material of varying length depending on the pipe diameter.

Fire Protection for Plastic Pipe Liners

A 2003 North Dakota DOT publication investigated options to minimize fire risk to polyethylene liners. Researchers found that polyethylene has a highly non-adhesive or inert surface that limits the possibility of using coatings on existing polyethylene liners. Although the coatings themselves are fire-resistant, in a sustained fire, the heat will be transferred to the polyethylene liner below, which could cause structural damage, melting or even burning of the liner. The study also used several marine fabric insulations in Hobas pipe with an inner layer, and discussed cost, application methods, flammability testing and other physical properties. However, the report does not mention the performance on the culvert, such as resistance to abrasion due to sediment and debris loading, or the water quality impacts during and after installation. Furthermore, this investigation suggests that concrete end caps provide "maximum protection against fires to the existing polyethylene liners since the concrete end caps will not allow the fire to start at the ends."

Related Resources

Research-Related Publications

An August 2011 report produced by the Electric Power Research Institute describes a method that can be used for raw water piping systems in nuclear power plants to protect HDPE piping located aboveground from “postulated fire events.” The publisher’s summary of a 2007 book chapter that examined the durability of polymer matrix composites exposed to elevated temperature and fire noted that “[t]he composites used in civil infrastructure pose an unusually high hazard because the polymers most often used are highly flammable and release copious amounts of heat, smoke, and fumes when they smolder and burn. The need to use low-cost materials in many infrastructure applications precludes the use of expensive flame-retardant polymers or fire-protective coatings.”

ADS, Inc.

A November 2015 handbook produced by ADS, Inc., a manufacturer of plastic pipes and related products, examines the durability of materials used for drainage. (*Note*: A January 9, 2019, conversation between Caltrans and ADS, Inc., produced the following findings:

- Coatings on thermoplastic pipe have been found to be ineffective as fire retardants. The ability for a coating to bond to the thermoplastic material is limited in durability. The coating will likely peel off, potentially causing chemical intrusion and impacting the water quality of the receiving water.
- Admixtures and additive substances used with thermoplastic resins to make the thermoplastic pipe more “fire-retardant” can dramatically change the structural characteristics of the thermoplastic pipe and compromise its integrity.)

Fire-Protective or Fire-Retardant Products

AkzoNobel, a Netherlands company, offers an intumescent epoxy coating developed to provide unspecified short-time fire protection that has been evaluated and tested extensively for marine use on ships and boats. A 2013 book examines advanced polymer concretes and composites, including “an advanced environmentally friendly and weather-resistant fire-protective coating for indoor and outdoor application to flammable substrates.” Avco Systems Division in Lowell, Massachusetts, has also developed improved intumescent coatings, which are based on three-component epoxy systems.

However, neither of these publications mentions the applicability of the coatings on culverts; their performance, such as resistance to abrasion due to sediment and debris loading; or the water and air quality impacts during and after installation.

Gaps in Findings

Findings from the survey and literature search did not uncover significantly different practices or a wide range of alternative products to inform or alter Caltrans’ current practices for the use or modification of plastic culverts in fire-prone areas.

Next Steps

Moving forward, Caltrans could consider:

- Contacting respondents who reported on practices to protect plastic culvert inlets to address vulnerabilities posed particularly by fire to learn more about these practices.
- Reviewing in detail the August 2011 Electric Power Research Institute publication that described the fire testing of four HDPE piping subassemblies.

Detailed Findings

Background

The 2018 wildfires in California prompted Caltrans to investigate vulnerabilities and possible solutions that may protect plastic pipes and culverts during wildfire events. Caltrans may use plastic in culverts in two situations:

- Designing and placing new plastic culverts.
- Rehabilitating existing culverts in the field with plastic pipe liners.

Chapter 850, Physical Standards, of Caltrans' Highway Design Manual discourages the use of plastic pipe and bituminous or plastic coatings in fire hazard areas due to potential burning or melting (see page 26 of this report for a citation for the Caltrans manual). Where similar high fire potential conditions exist for cross culverts, the designer may consider the following:

- Limiting the allowable pipe materials indicated on the alternative pipe listing to nonflammable material types.
- Using concrete endwalls that eliminate exposure of the pipe ends.
- Requiring that the end of flammable pipe types be replaced with a length of nonflammable pipe material.

While selection of pipe or culvert material during the design phase of a project is based on this guidance, retrofitting of existing plastic pipes and culverts in the field by maintenance forces or contractors is also a consideration. Because of the continued drought in California, flood hazard areas are increasing in surface area, and existing plastic pipes or culverts may now be more threatened than in previous years. For this reason, Caltrans is interested in learning about products or practices that can help protect plastic pipe culverts from being damaged during wildfires.

To assist with this effort, CTC & Associates summarized the results of a brief email survey of state departments of transportation (DOTs) that examined other agencies' practices and experience with plastic pipes and culverts. A literature search supplemented the survey results. Findings from the survey and literature search are preceded by further discussion below of plastic culvert use in California.

Plastic Culvert Use in California

A Caltrans Division of Maintenance database that tracks inspected culverts identified 15,695 pipes/culverts that are made of high-density polyethylene (HDPE); 2,463 pipes/culverts are made of polyvinyl chloride (PVC).

Two maps provide a spatial distribution of these HDPE and PVC culverts with a high and low probability of vulnerability, respectively, in different fire hazard severity zones (FHSZs) throughout the state:

- Attachment A displays the pipes/culverts with a high probability of vulnerability to fire in three FHSZs defined by California Department of Forestry and Fire Protection (CAL FIRE).

- Attachment B displays the pipes/culverts with a low probability of vulnerability to fire in the three FHSZs defined by CAL FIRE.

(A May 2007 CAL FIRE fact sheet indicates that "California law requires CAL FIRE to identify the severity of fire hazard statewide. These fire zones, called Fire Hazard Severity Zones are based on factors such as fuel, slope of the land and fire weather. There are three zones, based on increasing fire hazard: medium, high and very high"; see http://www.fire.ca.gov/fire_prevention/downloads/FHSZ_model_primer.pdf.)

Analyzing Culvert Vulnerability to Fire

The following describes how the two maps were developed:

- ***Data sources***. The maps were developed using two data sources:
    - *Source 1*. A list of the inspected plastic pipes/culverts obtained from Caltrans' Division of Maintenance Culvert Inspection Program as of December 8, 2018, in two categories: HDPE and PVC. (An Excel workbook providing these database results has been provided to Caltrans separately.) The Division of Maintenance estimates that the HDPE and PVC culverts on this list of inspected pipes and culverts represent about 65 percent of the agency's total culvert inventory.
    - *Source 2*. California FHSZ geographic information system (GIS) map obtained from the CAL FIRE web site at http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_maps. The FHSZ maps were updated in 2007/2008; CAL FIRE plans an update in 2018/2019.

- ***Analysis***. The following describes how the source data and mapping elements were used to develop the two maps:
    - *Step 1*: Pipes oriented longitudinally were excluded from the list of inspected plastic pipes/culverts (*Source 1*) since they are likely storm drains located below the ground and may not be vulnerable to wildfire hazards.
    - *Step 2*: Pipes/culverts with end treatment types *NET*, *NET_T*, *OD* and *RP* have a high probability of fire damage, as these pipes are exposed to air. Pipes with end treatment types *PI* and *UNDET* have a lower probability of fire damage because the exposure of this pipe above the ground is "unknown" or uncertain. The end treatment types described in the two maps, which are referenced in Section 11.0 of the Caltrans Culvert Inspection Manual (this manual is available to Caltrans staff members through the agency's intranet), are defined below:
        - *NET*. Pipes with no end treatments; these installations are culvert barrels that extend beyond the embankment and are located at the entrance to the system or the final outlet.
        - *NET_T*. Pipes with no end treatments and with a tee section to direct the flow in two directions; *NET_T* pipes are always outlets.
        - *OD*. A drain that collects surface runoff and is usually constructed of an asphalt berm or metal flume.
        - *RP*. A riser pipe, usually perforated; it extends the opening of a drainage inlet above the ground surface.

- *PI*. A location on a culvert where the direction of the culvert makes a radical change in direction; a *PI* can be below or above ground.
- *UNDET*. Undetermined; used to describe an end treatment that cannot be located or identified.

- *Step 3*: The FHSZ (*Source 2*) for State Responsibility Area (SRA) and the Local Responsibility Area (LRA) were merged, where each zone type (medium or moderate, high and very high fire hazard areas) is shown in a different colored layer.
- *Step 4*: Using the filtered list of vulnerability of the pipes/culverts (Step 2), two separate maps (high and low probability) were generated, overlaying the fire hazard map (Step 3).
- *Step 5*: The total number of pipes for each probability of vulnerability for a particular FHSZ was counted using ArcGIS tools.

Results of the Culvert Assessment

Attachments A and B indicate a high and low probability of vulnerability to fire, respectively. Each map includes a table with the number of HDPE and PVC culverts in each of the three fire hazard areas designated by CAL FIRE, categorized by the type of end treatment. Summary totals from the two tables are reflected in the table below.

Probability of Vulnerability	HDPE Culverts			PVC Culverts		
	Moderate Fire Hazard Area	High Fire Hazard Area	Very High Fire Hazard Area	Moderate Fire Hazard Area	High Fire Hazard Area	Very High Fire Hazard Area
High Probability	187	158	265	75	67	93
Low Probability	28	33	49	76	34	12

Related Resources

Spatial Distribution of Pipes/Culverts With High Probability of Vulnerability in Different Fire Hazard Severity Zones, Office of Hydraulics and Stormwater Design, Caltrans, December 19, 2018.
See Attachment A.
See above for a description of how this map displaying plastic culverts with a high probability of vulnerability to fire was developed.

Spatial Distribution of Pipes/Culverts With Low Probability of Vulnerability in Different Fire Hazard Severity Zones, Office of Hydraulics and Stormwater Design, Caltrans, December 19, 2018.
See Attachment B.
See above for a description of how this map displaying plastic culverts with a low probability of vulnerability to fire was developed.

Survey of Practice

Survey Approach

Caltrans distributed a survey by email to state DOT members of the American Association of State Highway and Transportation Officials (AASHTO) Research Advisory Committee Listserv. The survey included the following questions:

1. Do you have any policies, procedures, specifications or guidelines for the selection of pipe and culvert materials?
2. Do you have any policies, procedures, specifications or guidelines for the use of plastic pipe and culverts in general and in fire-prone areas specifically?
3. One idea was to put something in or cover the drainage inlet to provide protection. Do you have or know of research or guidelines in this area?
4. Do you know of any research or practices for fire protection or retardant for plastic pipes and culverts?

The full text of survey responses is presented in a supplement to this report.

Summary of Survey Results

Twenty-nine transportation agencies responded to the survey:

- Alaska.
- Colorado.
- Connecticut.
- Florida.
- Georgia.
- Illinois.
- Indiana (two responses).
- Iowa.
- Kansas.
- Louisiana.
- Maryland.
- Minnesota.
- Mississippi.
- Missouri.
- Montana.
- Nevada.
- New Hampshire.
- New Jersey.
- New Mexico.
- New York.
- North Carolina.
- North Dakota.
- Ohio.
- Oklahoma.
- Oregon.
- Utah.
- Vermont.
- Virginia.
- Washington.

The survey's key findings are summarized below in five topic areas:

- Selection of culvert and pipe materials.
- Use of plastic culverts in fire-prone areas.
- Protecting plastic culvert inlets.
- Research or practices related to fire protection.
- Related resources.

Selection of Culvert and Pipe Materials

Respondents took different approaches to responding to a request for agency policies, procedures or practices associated with the selection of culvert and pipe materials. Some provided only a link or reference to a publication, while others offered a brief description of agency practices. A small group of respondents simply acknowledged that their agencies had such specifications but offered no details about them. The latter type of response is not reflected in the table below that summarizes survey responses. Publications provided or referenced by respondents are cited in **Related Resources** beginning on page 18.

Guidance or Practices for Selection of Culvert and Pipe Materials

State	Description
Connecticut	All pipe-specific policies, procedures, specifications or guidelines are based on load factor and resistance design (LFRD) standards and guidance for highway applications.
Florida	Material selection for culvert applications is determined by the material's functionally equivalent performance in three areas: durability (projected service life), structural capacity and hydraulic capacity. See page 18 for a link to the agency's Drainage Manual; Chapter 6, Optional Culvert Materials, includes material recommendations based on these performance factors.
Georgia	Plastic pipe is not allowed on interstates; there are no limitations on side drains. Storm drain is limited to roadways with average daily traffic (ADT) of 15,000 or less.
Illinois	Design guidelines for pipe culverts include pipe diameter and soil pH limitations and the class of pipe culverts (based on ADT) for various applications. See page 19 for links to agency specifications on class of pipe culverts and permitted pipe materials.
Indiana	Approximately 20 years ago, the agency developed a pipe material selection software program that is still in use. • Design engineers enter various parameters into the program, including pipe type (use), design service life, pH (acidity/alkalinity of water and soil), slope, installation location (abrasive or nonabrasive) and cover. • The program generates a list of approved pipe materials that will be allowed for a particular pipe or culvert structure. • Contractors choose from allowed material types for a particular location that are shown in a pipe material table in the plans. See page 20 for a link to the pipe material selection software program.
Iowa	Agency policy allows flexible pipe (HDPE or corrugated metal pipe (CMP)) and concrete pipe for projects where the ADT is less than 3,000 vehicles per day (vpd) and the highway is not a National Highway System (NHS) route. Highways with an ADT greater than 3,000 vpd and designated as an NHS route require concrete culverts.
Kansas	Material use is based on annual ADT, soil conditions, resistivity of soil and water conditions.

Guidance or Practices for Selection of Culvert and Pipe Materials	
State	**Description**
Maryland	Plastic pipe is allowed where it meets service life and loading criteria. No fire-related guidance has been developed.
Mississippi	Design criteria for cross, side, storm and underdrains are based on a 50-year design life for most drains and include criteria for various pipe sizes and alternate materials to consider. See page 21 for a link to the agency's design criteria.
Missouri	Agency specifications identify size limitations for double-wall, triple-wall, corrugated and steel-reinforced polyethylene pipe and PVC pipe.
Montana	Generally, the agency allows plastic pipe for storm drains, drainage pipe and irrigation pipelines on a case-by-case basis.
Nevada	The agency does not allow the placement of plastic pipes under travel lanes of high-volume roadways in the event of a pipe failure due to fire. However, plastic pipe is allowed under shoulder sections where a failure wouldn't close the road. Additionally: • No plastic pipe larger than 24 inches is constructed on the DOT's road system in the Las Vegas metropolitan area because of the potential that people experiencing homelessness will camp and light fires for warmth inside pipes greater than 24 inches in diameter. • Plastic pipes are avoided in mountainous areas where a failure would cause a lengthy detour or could isolate a community. Due to the slow rate of burn, it is not generally thought that a plastic pipe would allow a fire to spread by passing under a roadway, but the agency does consider access for emergency medical service vehicles when placing plastic pipe.
New York	Selection criteria are based on service life, design load (fill height), price and timeliness.
North Carolina	Guidance is based on structural competency and durability. Use of plastic pipe is currently restricted to nonprimary routes, with no restrictions or recommendations for fire-prone areas. The state's fire-prone areas primarily exist in national forest and are related to prescribed burns.

North Dakota	• Plastic pipes are only allowed under paved roadways if all the following conditions are met:
	  ○ Pipe material is polypropylene pipe (Type S).
	  ○ Pipe diameter is 36 inches or less.
	  ○ Paved roadway is on either a Level 2 or 3 State Strategic Freight System route (see http://www.dot.nd.gov/divisions/planning/freight/ for a link to the freight map).

Guidance or Practices for Selection of Culvert and Pipe Materials	
State	**Description**
North Dakota (continued)	○ Paved roadway is classified as a state corridor, district corridor or district collector. ○ Paved roadway has a current ADT less than 2,000. • Concrete is the only type of pipe material allowed to be installed under divided highways with depressed medians.
Ohio	The agency's open pipe criteria allow multiple material options from which the contractor can select. In some cases, engineering needs may require specification of a particular material. Districts are encouraged to contact the central office for approval of sole source materials.
Oregon	Agency practice is to allow the contractor to select pipe material from a project-specific "pipe data sheet." The DOT allows most types of materials unless there is a specific reason that a material type should not be used.
Utah	Thermoplastic pipe (HDPE, PVC, polypropylene and steel-reinforced thermoplastic ribbed pipe): • Use an AASHTO National Transportation Product Evaluation Program (NTPEP) compliant supplier of thermoplastic pipe. • Do not use in permanent aboveground installations. • Do not use greater than 36-inch diameter for PVC pipe. • Do not use greater than 60-inch diameter for HDPE, polypropylene and steel-reinforced thermoplastic ribbed pipe. • Use bell and spigot joints with an elastomeric rubber gasket. (Refer to ASTM F 477.)

Use of Plastic Culverts in Fire-Prone Areas

Six respondents described agency policies or practices that address the use of plastic culverts in fire-prone areas. None of these practices are specifically in response to the threat of wildfires.

- Colorado DOT exercises caution in using plastic culvert pipes in agricultural areas where ditches are burned seasonally to clean out old vegetation. With the many wildfires Colorado has experienced over the last several years, the respondent noted that the practice of burning ditches is less used and not recommended. The respondent also mentioned that he would require the use of metal or concrete material pipes in areas that might be at high risk of fire.
- Minnesota DOT issued an April 2017 Technical Memorandum that provides guidance on consideration of fire risk:

  > Plastic pipe should not be used where there is a likelihood of exposure to fire without fire mitigation. Fire mitigation alternatives include concrete slope paving, concrete headwall and concrete aprons. Use of fire mitigation alternatives requires a design detail in the plan and a special provision indicating additional cost of fire mitigation is included in the contract unit price of the pipe pay item.

  See **Related Resources** on page 20 for the Technical Memorandum.

- While Montana DOT's policies do not specifically address fire-prone areas, the agency does consider fire risk in connection with ditch burning, a common practice in Montana to clean irrigation ditches and pipes.
- Nevada DOT does not allow the placement of plastic pipes under travel lanes of high-volume roadways in the event of a pipe failure due to fire. However, plastic pipe is allowed under shoulder sections where a failure wouldn't close the road.
- In North Dakota, the primary fire concern arises from landowners with property adjacent to the highway who opt to burn ditches to control vegetation. Plastic pipe is not typically allowed in these areas under the mainline.
- Oregon DOT does not use plastic pipes when the agency is aware of a fire concern. The respondent did not cite a specific policy or guidance document that codifies this practice.

Protecting Plastic Culvert Inlets

The table below highlights agency practices to protect the end sections, or inlets, of plastic culverts.

Agency Practices to Protect Plastic Culvert Inlets

State	Practice
Colorado	The agency requires the use of metal end sections at the ends of plastic pipes. While this modification was not specifically intended to protect plastic pipes from burning, it does have that effect. (Note that the Colorado DOT Drainage Design Manual, cited on page 18, indicates that a full concrete headwall "shall be considered for any size of plastic culvert pipes if the project site is located in areas where risk of fire is relatively high.")
Florida	Agency policy is to not use unprotected plastic pipe on drainage end sections to prevent deterioration due to UV exposure and exposure to heat and fire.
Georgia	Standard 1030P, Thermoplastic Pipe (revised September 2016), indicates the requirements for concrete or metal end sections for both ends of thermoplastic pipes.
Illinois	Agency guidance requires that for "all pipe culverts, with the exception of entrance culverts, a nonplastic end treatment must be specified. An end treatment for entrance culverts, which can protect the culvert ends from being crushed and allow for proper grading of the transverse slopes, will be at the designers' option." The respondent also noted that while agency guidance doesn't mention fire resistance, a non-plastic end section could provide limited protection from small fires.
Minnesota	Agency guidance recommends avoiding the use of plastic pipe where there is a likelihood of exposure to fire without fire mitigation alternatives, which include concrete slope paving, concrete headwall and concrete aprons.

Agency Practices to Protect Plastic Culvert Inlets	
State	**Practice**
Mississippi	Agency guidance requires that all pipe materials other than concrete have a concrete end section.
Montana	While agency policies do not specifically address fire-prone areas, if the agency is concerned about the possibility of ditch burning, a concrete headwall or other concrete end section would be included in the culvert design. The respondent also noted that agency policies are being updated.
Nevada	The respondent commented on a practice by unspecified other agencies to place a plastic pipe under a roadway that substitutes CMP or reinforced concrete pipe (RCP) for the last segment of pipe on either side. This practice is expected to decrease the likelihood that a fire could compromise the plastic pipe and, in turn, the roadway.
North Dakota	For approaches, the agency typically requires the application of a nonflammable segment on the ends of each plastic pipe.
Ohio	The respondent commented on other DOTs' use of metal pipe ends on plastic pipe to shield the pipe from the negative impacts of UV exposure. He also mentioned a recent event in his state: A metal pipe with bituminous coating caught on fire after diesel fuel from a crashed semitrailer drained to the metal pipe. The pipe's bituminous material burned and the pipe collapsed.
Oklahoma	An agency special provision for plastic pipe mandates a concrete end section of plastic pipe in all installations, regardless of location.

Research or Practices Related to Fire Protection

Only the Florida DOT respondent reported on research that sought to examine fire protection for culverts, noting that the agency performed a flammability study on HDPE drainage pipe "several years ago," and the results supported the agency's policy to not use unprotected plastic pipe on drainage end sections to prevent deterioration due to UV exposure and exposure to heat and fire. The respondent also noted that "[f]lammability is more of a concern on pipe ends since oxygen limitation would prevent flame spread inwards."

While the respondent did not provide further details of this study, the literature search that supplemented this project's survey findings and an email response from Florida DOT identified repeated references to a July 1994 Florida DOT study, High Density Polyethylene Pipe Fire Risk Evaluation (see Attachment C and page 18 for further details).

The North Carolina DOT respondent did not cite previous or ongoing research but did note that North Carolina State University's College of Textiles maintains a fire laboratory that could be used should the agency determine that a collaborative effort is warranted. Information about the Textile Protection and Comfort Center is available at https://textiles.ncsu.edu/tpacc/heat-and-flame-protection.

Related Resources

Colorado

Chapter 9, Culverts, CDOT Drainage Design Manual, Colorado Department of Transportation, undated.
https://www.codot.gov/programs/environmental/water-quality/documents/drainage-design-manual/drainagedesignmanual_chapter09_culverts.pdf
From page 9-27 of the manual (page 27 of the PDF):

> **Fire Protection**
> Full concrete headwall shall be considered for any size of plastic culvert pipes if project site is located in areas where risk of fire is relatively high.

CDOT Pipe Material Selection Guide, Colorado Department of Transportation, April 2015.
https://www.codot.gov/business/designsupport/bulletins_manuals/cdot-pipe-material-selection-guide/pipe-guide/at_download/file
This selection guide does not address applications in fire-prone areas.

Florida

Section 430, Pipe Culverts, Standard Specifications for Road and Bridge Construction, Florida Department of Transportation, January 2019.
https://www.fdot.gov/docs/default-source/content-docs/programmanagement/implemented/specbooks/january2019/files/119eBook.pdf
This section begins on page 454 of the specifications (page 462 of the PDF).

Section 948, Optional Drainage Products and Liner Repair Systems, Standard Specifications, Florida Department of Transportation, January 2019.
https://www.fdot.gov/docs/default-source/content-docs/programmanagement/implemented/specbooks/january2019/files/119eBook.pdf
This section begins on page 1116 of the specifications (page 1124 of the PDF).

Drainage Manual, Drainage Section, Florida Department of Transportation, January 2019.
https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/content2/roadway/drainage/files/drainagemanual.pdf?sfvrsn=e0fd0105_0
See Chapter 6, Optional Culvert Materials, which begins on page 63 of the manual (page 68 of the PDF).

High Density Polyethylene Pipe Fire Risk Evaluation, Corrosion Research Laboratory, State Materials Office, Florida Department of Transportation, July 1994.
See Attachment C.
From the executive summary:

> The study included field burn tests, a state-by-state survey of HDPE pipe usage and experience and standard laboratory burn tests on polyethylene coupons. Also included in the field tests was a burn test on a mitered end section with concrete apron as presently proposed for FDOT approval by the plastic pipe industry.
>
> The results of the study indicate that HDPE pipe is not at significant risk of fire when installed to present standards and exposed to fire such as that which may be encountered in roadside grass fires. The results of the burn test on the mitered end section indicate that this design is susceptible to ignition in a roadside grass fire.

The July 1994 report includes the following on page 1 of the report (page 7 of the PDF):

> At present, HDPE may be used in diameters up to 0.91 meters (36″). Approved applications are for cross drains, edge drains, underdrains, gutter drains and side drains. In all applications the pipe ends must terminate in either a concrete headwall, drainage structure or non-plastic mitered end section with a concrete apron.

Based on the field burn tests, where concrete headwall and metered end section were used with different combinations of vegetation density, the report's conclusions, which begin on page 16 of the report (page 22 of the PDF), indicate that "[p]olyethylene pipe installed to present FDOT standards is not at significant risk of fire when exposed to expected grass fire intensities" and "[i]n the event of an actual in-pipe fire, the burn rate is expected to be very low (0.0085 m/minutes) or (1.7 ft./h)." Laboratory tests showed that the flash point of polyethylene pipe and asphalt pipe coating was 740°F and 595°F, respectively; the burn point of these materials was 750°F and 620°F, respectively.

A summary of the nationwide survey conducted for the July 1994 study indicated that "[o]ut of 41 states reporting, only four reported incidents of fire and the total reported number of fires was eight." Survey results also indicated that "the computed rate at which fires have occurred is one fire per state every 48 years" (see page 14 of the report; page 20 of the PDF). The report's assessment of fire risk noted that "[b]ased on the results of this study, the overall risk of fire to polyethylene pipe is considered minimal" (see page 15 of the report; page 21 of the PDF).

Georgia

Standard 1030P, Thermoplastic Pipe, Construction Standards and Details, Georgia Department of Transportation, September 2016.
http://mydocs.dot.ga.gov/info/gdotpubs/ConstructionStandardsAndDetails/1030P_1030p.pdf
This document provides drawings, design standards and details for thermoplastic pipe.

Supplemental Specifications Modifying the 2013 Standard Specifications Construction of Transportation Systems, Georgia Department of Transportation, 2016 Edition, November 2016.
http://www.dot.ga.gov/PartnerSmart/Business/Source/special_provisions/2016%20Supplemental%20Specifications/2016SupplementalSpecBook.pdf
Relevant sections include the following:

- Section 207, Excavation and Backfill for Minor Structures (page 57 of the manual; page 60 of the PDF).
- Section 550, Storm Drain Pipe, Pipe-Arch Culverts and Side Drain Pipe (page 134 of the manual; page 137 of the PDF).
- Section 845, Thermoplastic Pipe (page 251 of the manual; page 254 of the PDF).

Illinois

Section 40-3.07(d), Class of Pipe Culverts and Storm Sewers, Bureau of Design and Environment Manual, Illinois Department of Transportation, March 2017.
http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Design-and-Environment/Illinois%20BDE%20Manual.pdf
See page 40-3.07 of the manual (page 3059 of the PDF) for information about the class of pipe

culvert to be specified for specific conditions. See the citation below for a description of the pipe materials grouped by class.

Section 542, Pipe Culverts, Standard Specifications for Road and Bridge Construction, Illinois Department of Transportation, April 2016.
http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Guides-&-Handbooks/Highways/Construction/Standard-Specifications/Standard%20Specifications%20for%20Road%20and%20Bridge%20Construction%202016.pdf
This section begins on page 429 of the specifications (page 445 of the PDF). Tables within this section describe the plastic pipe permitted under the specifications.

Indiana

Pipe Material Selection Software, Version 1.01214, Indiana Department of Transportation, undated.
https://hma.indot.in.gov/pipes/
This web site indicates that the "pipe material selection program is a tool to assist when compiling a list of acceptable pipe materials for pipe types designated as 1, 2, 3 and 5. Due diligence on the part of the designer is required prior to incorporating the final selection of acceptable materials." This software program is also briefly described on page 13 of this report.

E715-PLSC, Pipe Service Life Criteria, Section 700, Structures, Standard Drawings, Indiana Department of Transportation, September 2017.
https://www.in.gov/dot/div/contracts/standards/drawings/sep18/e/700e/e700%20combined%20pdfs/E715-PSLC.pdf
This is the series of drawings referred to by the Indiana DOT respondent, who noted that the "general guidelines for plastic pipe are covered by our standard drawings, the 715-PSLC series. We do not have any fire-prone areas or guidelines."

Maryland

Culverts: Highway Drainage Manual Design Guidelines, Highway Hydraulics Division, Maryland Department of Transportation, September 2009.
https://www.roads.maryland.gov/OHD2/HDM_design_guidelines_culverts.pdf
Page 1 of this guidance describes material selection:

> Material selection shall include consideration of service life. The expected service life is depend[e]nt on numerous variables such as soil characteristics, water chemistry, bedload, groundwater levels, and use of various protective coatings. The design service life of a drainage facility is defined as the expected maintenance free service life of each installation.

Minnesota

Use of Plastic Pipe for Storm Sewer and Culverts on Trunk Highways, Technical Memorandum No. 17-05-B-02, Engineering Services Division, Minnesota Department of Transportation, April 2017.
https://www.dot.state.mn.us/bridge/pdf/hydraulics/drainagemanual/tm1705b02-1846930-v2.pdf
This Technical Memorandum provides "updated design criteria on the use of plastic pipe for storm sewer and culverts. Detailed information is given for the use of corrugated polyethylene (CP) pipe, polypropylene (PP) pipe, and polyvinyl chloride (PVC) pipe." *From page 3 of the memorandum*:

Plastic pipe should not be used where there is a likelihood of exposure to fire without fire mitigation. Fire mitigation alternatives include concrete slope paving, concrete headwall and concrete aprons. Use of fire mitigation alternatives requires a design detail in the plan and a special provision indicating additional cost of fire mitigation is included in the contract unit price of the pipe pay item.

Polyvinyl Chloride (PVC) pipe is sensitive to ultra violet (UV) radiation and exposure to sunlight may accelerate deterioration. It is recommended PVC be limited to applications and locations where pipe is not exposed to UV radiation.

Mississippi

MDOT Pipe Culvert Material Design Criteria, Mississippi Department of Transportation, November 2007.
See Attachment D.
This document describes the design criteria for cross, side, storm and underdrains. There are no references to material selection for fire-prone areas.

Missouri

Section 724, Pipe Culverts, Missouri Standard Specifications for Highway Construction, Missouri Department of Transportation, 2018.
https://www.modot.org/sites/default/files/documents/2018%20Missouri%20Standard%20Specific%20-%20MHTC%20%28July%202018%29.pdf
See page 444 of the specifications (page 445 of the PDF) for a table specifying the type of pipe or the group of permissible types of pipe that may be used by contractors, including rigid and flexible (metal and thermoplastic) pipe.

Montana

Alternative Culvert Pipe Material Selection Guidelines, Memorandum, Montana Department of Transportation, June 2007.
https://www.mdt.mt.gov/other/webdata/external/cadd/design_memos/2007-06-12_ALTERNATIVE_CULVERT_PIPE_MATERIAL.PDF
Table 2, Guidelines for Optional Pipe Material Selection, on page 8 of the memorandum indicates when HDPE pipe is among the materials to be considered for a particular application.

New Mexico

Drainage Design Manual, New Mexico Department of Transportation, July 2018.
http://dot.state.nm.us/content/dam/nmdot/Infrastructure/Drain_Design_Manual.pdf
From page 8-6 of the manual (page 415 of the PDF):

801.2.4 Plastic Culverts
Plastic pipe includes High Density Polyethylene (HDPE) culverts and Polyvinyl Chloride (PVC) culverts. They can handle all soil and water conditions given in Table 801-1. Other types of plastic pipes have come into the market and future determination of their CRN [corrosion resistance number] values will need to be evaluated.

Standard Specifications for Highway and Bridge Construction, New Mexico Department of Transportation, 2014.
http://dot.state.nm.us/content/dam/nmdot/Plans_Specs_Estimates/2014_Specs_For_Highway_And_Bridge_Construction.pdf
Section 570, Pipe Culverts, begins on page 498 of the manual (page 505 of the PDF).

North Dakota

Chapter V, Hydraulic Studies and Drainage Design, Design Manual, North Dakota Department of Transportation, 2016.
http://www.dot.nd.gov/manuals/design/designmanual/Chapter%205.pdf
Section V-05, Pipe Material Selection, begins on page 154 of the chapter (page 155 of the PDF).

Ohio

Volume 2: Drainage Design, Location and Design Manual, Office of Hydraulic Engineering, Ohio Department of Transportation, January 2019.
http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Location%20and%20Design%20Volume%202/LD%20Volume%202%20Archive%2012013/ODOT-Location%20and%20Design%20Manual%20Volume%20II.pdf
This manual addresses the height of cover, pipe roughness coefficient and permissible uses of thermoplastic pipe.

Utah

Standard Specifications for Road and Bridge Construction, Utah Department of Transportation, January 2017.
https://www.udot.utah.gov/main/uconowner.gf?n=31730316757114651
Section 02610, Drainage Pipe, begins on page 276 of the PDF. Specifications for thermoplastic pipe (HDPE, PVC, polypropylene and steel-reinforced thermoplastic ribbed pipe) are provided on page 281 of the PDF.

Virginia

Selection of Pipe Type: Pipe Type Options for Culverts and Storm Sewer to be Determined by Engineer, Instructional and Informational Memorandum, Location and Design Division, Virginia Department of Transportation, October 2016.
http://www.extranet.vdot.state.va.us/locdes/electronic_pubs/iim/IIM254.pdf
From page 1 of the memorandum: Selection of allowed pipe type options (concrete, metal or plastic, and in some cases other materials) for culverts and storm sewer will be made by the Engineer based on information contained in Chapters 3 and 8 in the VDOT Drainage Manual and Standard PC-1 in the VDOT Road and Bridge Standards. The Engineer will also select the allowed joint types to be used.

Drainage Manual, Location and Design Division, Virginia Department of Transportation, July 2017.
Downloadable zip folder available at http://www.virginiadot.org/business/locdes/hydra-drainage-manual.asp
See Chapters 3 and 8 for information related to culverts.

Section 100: Drainage Items, Road and Bridge Standards, Virginia Department of Transportation, 2016.
http://www.extranet.vdot.state.va.us/LocDes/Electronic_Pubs/2016_Road%20and%20Bridge/CS100.pdf
Specifications and drawings associated with culvert pipes appear throughout this document.

Related Research and Other Resources

An expansive search of domestic and international resources sought information about the practices and products that could be used in connection with plastic culverts in fire-prone areas. The literature search extended beyond recently published resources to consider publications dating back to the 1980s and sought information about the use of plastic in applications other than transportation infrastructure that might be relevant to Caltrans' interests. The search identified relatively little in the literature that goes beyond echoing or recommending Caltrans' current practices to consider alternatives to plastic in fire-prone areas and modifications of plastic culverts to protect them from fire.

The publications below are organized into three topic areas:

- National guidance.
- Other agency guidance, practices and experience.
- Related resources.

National Guidance

NCHRP Synthesis 474: Service Life of Culverts, Michael Maher, Gregory Hebeler and Andrew Fuggle, 2015.
Publication available at https://www.nap.edu/catalog/22140/service-life-of-culverts
This report includes two references to fire risk and fire damage associated with culverts. *From page 17 of the report (page 28 of the PDF)*:

> **Fire Damage**
> Although the risk of damage to storm drainage systems is quite low, under certain circumstances, such as forest fires, damage to culverts can occur. In forest fires, all pipe material types can sustain damage from exposure to extremely high temperatures. While thermoplastic pipes would be the most vulnerable, the National Fire Protection Association (NFPA 2012) has given both polyethylene and polypropylene a rating of 1 (Slow Burning) on a scale of 0 to 4, where higher ratings indicate a greater vulnerability.

From page 29 of the report (page 40 of the PDF):

> Asphalt coatings can be flammable. Where the risk of fire is high, concrete end walls or other "insulating" end treatments need to be considered. Special care must be taken during shipping and installation to ensure that the coating is not damaged or removed.

Related Resource:

> **NFPA 704, Standard System for the Identification of the Hazards of Materials for Emergency Response**, National Fire Protection Association, Current Edition 2017. Publication available at https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=704
> A frequently asked questions document describes NFPA 704 as providing "a simple, readily recognized, easily understood system for identifying the specific hazards of a material and the severity of the hazard that would occur during an emergency response. The system addresses the health, flammability, instability and special hazards presented from short-term, acute exposures that could occur as a result of a fire, spill or similar emergency."

Decision Analysis Guide for Corrugated Metal Culvert Rehabilitation and Replacement Using Trenchless Technology, John C. Matthews, Jadranka Simicevic, Maureen A. Kestler and Rob Piehl, Forest Service, United States Department of Agriculture, December 2012.
https://www.fs.fed.us/t-d/pubs/pdfpubs/pdf11771810/pdf11771810Pdpi72.pdf
From page 26 of the report (page 34 of the PDF):

> North Dakota Department of Transportation incurred severe damage to some polyethylene liners installed in corrugated metal pipes due to ditch fires. "Cost Effective Non-Flammable Pipe Liners" (Katti et al. 2003) investigates options to address the flammability of these liners. The research reviews several coatings that could be applied to the inside of polyethylene liners, cast-in-place liners (manufactured by Inliner, Insituform, U-Liner), and Hobas pipe. The Hobas pipe was found to be the best solution; however, it has to be fitted with concrete end caps to ensure fire resistance.
>
> In 2007, the Cascade Complex fires in the Payette National Forest in Idaho resulted in the destruction of 142 high-density polyethylene culverts ranging in diameter from 18 to 36 inches, 41 wood culvert inlet headwalls, and 50 high-density polyethylene culvert downspouts (figure 9). The Forest Service and the FHWA [Federal Highway Administration] recommend concrete or masonry headwalls for flammable plastic culverts and liners in forest environments where fire is a possibility.

Related Resource:

> **Cost Effective Non-Flammable Pipe Liners**, Kalpana Katti, Dinesh Katti and Frank Yazdani, North Dakota Department of Transportation, 2003.
> http://www.dot.nd.gov/divisions/materials/research_project/ndsu0101final.pdf
> Researchers were tasked with investigating potential mitigation methods to minimize fire risk to CMPs that have been retrofitted with polyethylene (PE) liners. While these liners were deemed to be cost-effective and met structural and hydraulic properties, North Dakota DOT observed that numerous liners had been damaged from ditch fires.
>
> See page 13 of the report (page 16 of the PDF) for the authors' recommendations "as potential solutions to address the flammability issue of the current PE pipeliners."

Culvert Assessment and Decision-Making Procedures Manual for Federal Lands Highway, John H. Hunt, Stephen M. Zerges, Brian C. Roberts and Bart Bergendahl, Federal Highway Administration, September 2010.
See Attachment E.

While this publication does not address fire in its text, Appendix B, Photographic Guide for Culvert Assessment Tool, which begins on page B.1 of the report (page 99 of the PDF), includes a photograph of a plastic culvert with fire damage and the resultant severe deformation at the pipe ends (see page B.41 of the report, page 139 of the PDF).

NCHRP Report 225: Plastic Pipe for Subsurface Drainage of Transportation Facilities, R.E. Chambers, T.J. McGrath and F.J. Heger, October 1980.
http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_225.pdf
This report includes a number of references to the use of plastic pipe and the impact of fire:

From page 15 of the report (page 23 of the PDF):

> Plastic pipe burns. A risk of destruction exists if flaming materials are introduced into a drainage system or if a fire occurs during storage. A common maintenance practice has been to burn off grass and brush on areas adjacent to highways. Plastic pipe should be terminated underground, and noncombustible pipe should be installed from this terminus to areas that may be exposed to these or other accidental fires.

From page 44 of the report (page 52 of the PDF):

> *Fire*—Plastic pipe burns. It should be protected from direct exposure to fires at its terminus.

From page B-47 of the report (page 102 of the PDF):

> Georgia allows the use of coiled tubing in diameters less than 6 in. (152 mm), but requires straight sections which are 10 ft (3 m) or greater in length for 6 in. (152 mm) and larger sizes. Problems have been encountered with dilation of perforation slots, and cracks propagating from such slots in 6 in. (152 mm) diameter coiled pipe in cold weather. These problems have not been encountered in coiled pipe having diameters less than 6 in. (152 mm).
>
> The corrugated PE tubing is terminated at outlets with a 3-ft (0.9 m) length of corrugated metal pipe (Fig. B-15), as a protection against fire and other damage.

Other Agency Guidance, Practices and Experience

Canada

Circular Culverts and Storm Sewers: MTO (Ministry of Transportation of Ontario) Gravity Pipe Design Guidelines, Ministry of Transportation of Ontario, May 2007.
https://documents.ottawa.ca/sites/default/files/documents/con043112.pdf
Chapter 7, Durability Design Evaluation, addresses fire resistance. *From page 63 of the guide (page 71 of the PDF)*:

> Gravity pipe storm sewers and culvert in Ontario are generally only subjected to fire damage in rare occurrences associated with traffic accidents and gasoline or chemical spillage. Gasoline based fire can readily induce temperatures above 600°C (the temperature of a typical camp fire).
>
> Neither concrete nor steel will support combustion. According to Buchanan (2001), concrete will not sustain damage unless subjected to temperature exceeding 350°C, and loses about

half its strength at a temperature of 625°C. Steel remains undamaged under a temperature of 400°C, and experiences a drop of about 50% in yield stress at 625°C (given normal stability factors of about 2, this temperature is a typical design limit for considerations of fire resistance). HDPE pipe, the polymer laminate on steel pipe, and to a lesser extent PVC pipe, have medium susceptibility to fire, since they will generally not self-sustain fire, but will burn when exposed to flame from another combustion source and where the air flow is adequate. Nelson (1995) describes these polymers as "intrinsically flame retardant" since the combusted material tends to remain in place over the residual material. Tested to ASTM D1929, the flash points of HDPE and PVC are 340°C and 395°C respectively. PVC has one of the lowest fire susceptibilities among thermoplastic materials. HDPE is less fire resistant, and has melt temperatures between about 130°C and 200°C.

Florida Department of Transportation Report 94-7A (FDOT 1994) describes a detailed investigation of potential damage to HDPE culverts from grass fires. That report concludes that damage during grass fires of expected intensity is unlikely, and that typical burn rates of 0.52 m per hour are insufficient to generate damage prior to arrival of fire fighting equipment and personnel (although this may not be the case in remote areas of Ontario). They do conclude, however, that grass fire damage can result to mitred end sections, and recommend use of end sections that do not support combustion in that case.

Durability and Performance of Gravity Pipes: A State-of-the-Art Literature Review, Jack Q. Zhao, S. Kuraoka, T.H.W. Baker, P. Gu, J.-F. Masson, S. Boudreau and R. Brousseau, Institute for Research in Construction, National Research Council of Canada, 1998.
Publication available at http://publications.gc.ca/collections/collection_2013/cnrc-nrc/NR35-18-1998-eng.pdf
A discussion of fire resistance begins on page 28 of the report (page 35 of the PDF). The authors address the temperatures at which plastic pipe deforms and cite a 1991 North Carolina DOT study that concluded "any application where the ends of HDPE pipe are exposed, such as culvert applications, makes it susceptible to fire damage." The 1991 North Carolina DOT report, cited as Performance Evaluation of AASHTO M 294 Type "S" Polyethylene Pipe, does not appear to be publicly available.

California

Chapter 850, Physical Standards, Highway Design Manual, California Department of Transportation, various dates.
http://www.dot.ca.gov/design/manuals/hdm/chp0850.pdf
Section 855.5, Material Susceptibility to Fire, begins on page 850-34 of the manual (page 34 of the PDF) and includes the following:

> Cross culverts and exposed overside drains are the placement types most subject to burning or melting and designers should consider either limiting the alternative pipe listing to non-flammable pipe materials or providing a non-flammable end treatment to provide some level of protection.
>
> Plastic pipe and pipes with coatings (typically of bituminous or plastic materials) are the most susceptible to damage from fire. Of the plastic pipe types which are allowed, PVC will self extinguish if the source of the fire is eliminated (i.e., if the grass or brush is consumed or removed) while HDPE can continue to burn as long as an adequate oxygen supply is present. Based on testing performed by Florida DOT, this rate of burning is fairly slow, and often self extinguished if the airflow was inhibited (i.e., pipe not aligned with prevailing wind or ends sheltered from air flow).

> Due to the potential for fire damage, plastic pipe is not recommended for overside drain locations where there is high fire potential (large amounts of brush or grass or areas with a history of fire) and where the overside drain is placed or anchored on top of the slope.
>
> Where similar high fire potential conditions exist for cross culverts, the designer may consider limiting the allowable pipe materials indicated on the alternative pipe listing to non-flammable material types, use concrete endwalls that eliminate exposure of the pipe ends, or require that the end of flammable pipe types be replaced with a length of non-flammable pipe material.

Stream Crossing Alternatives, Pete Cafferata, California Department of Forestry and Fire Protection, December 2013.
http://cecentralsierra.ucanr.edu/files/178224.pdf
Slide 14 of this presentation highlights the pros and cons of the use of plastic pipe, noting that fire damage is the "biggest problem." Slides 15 through 17 provide photos of plastic pipe damaged by fire. See also slides 144 and 145 for photos of plastic culverts damaged by fire in the 2013 Rim Fire.

Burn Area Recovery Task Force (BARTF) Report: Riverside County Rosa Fire, Multi-Agency Support Group, Burn Area Recovery Task Force, December 2007.
https://w3.calema.ca.gov/Operational/OESHome.nsf/PDF/Fire%20-%20BARTF/$file/Rosa_Rivside.pdf
This report was prepared to "identify and prioritize emergency protective measures to address post-fire flooding, erosion and debris flow hazards." Page 2 of the report (page 3 of the PDF) describes impacts to the Santa Margarita River/Sandia Canyon and Lower Murrieta Creek from the 2007 Rosa Fire in Riverside County:

> Additionally, plastic culverts were used by one of the orchard operations within the burned area for roadway and orchard drainage. In the orchard, it appears plastic culverts were installed down the natural watercourses and the watercourses subsequently filled with dirt and debris. The fire melted many of the plastic culverts and the drainages are now littered with this debris. In a heavy flow event, there is a likelihood culverts could be blocked resulting in fill failures and degradation to the watercourse, road damage, and in some cases potential for isolation to landowners with driveways that cross drainages.

Colorado

Polyethylene Pipes for Use as Highway Culverts, Thomas R. Hunt, Colorado Department of Transportation, July 1991.
https://www.codot.gov/programs/research/pdfs/1991-research-reports/polytheylenepipes.pdf
This report describes the 1988 replacement of CMP with corrugated polyethylene pipes. The agency expected the new plastic pipes to fare better than metal pipes in the area's corrosive alkaline environment. Examination of the new installations after three years identified an issue with one of the culverts. *From page 26 of the report (page 32 of the PDF):*

> There was a problem with fire in one of the culverts. A large amount of sawdust from the summer of 1990, this sawdust was somehow ignited, and burned in the ditch and about ten feet into the culvert. The soil around the culvert was exposed, but did not collapse. A new segment of pipe was installed in its place. According to the manufacturer, the temperature at which the polyethylene pipes melt is 450°F.

See pages 30 and 31 of the report (pages 36 and 37 of the PDF) for images of plastic pipes after burning.

Iowa

Investigation of High Density Polyethylene Pipe for Highway Applications, Final Report: Phase I, F.W. Klaiber, R.A. Lohnes, T.J. Wipf and B.M. Phares, Iowa Department of Transportation, January 1996.
http://publications.iowa.gov/19677/1/IADOT_hr373phase1_Investigation_High_Density_Polyethylene_1996.pdf
Researchers surveyed Iowa county engineers to learn about their use of HDPE for culvert pipes. Results of a Tennessee survey of state DOTs are also included in this report along with a review of literature that examined the flammability of HDPE. Below is an excerpt of the literature review (beginning on page 28 of the report, page 40 of the PDF):

> **2.6 Flammability and Ultraviolet Radiation**
>
> A study completed by the Phillips Chemical Company (1983) concluded the following about polyethylene's flammability. Testing according to ASTM D635 and MVSS 302 classify polyethylene as burning with a rate of 1 in. per minute. Flash temperature was found to be 645°F with a self-ignition temperature of 660°F. In addition, the minimum concentration of oxygen which will just support combustion is 17.4%.
>
> From a study performed by the Florida Department of Transportation (Kessler and Powers 1994), it was concluded that FDOT's present policies concerning the use of HDPE pipe were adequate concerning fire safety. The study included field burn tests, a survey of the usage and experience of state DOT's with HDPE pipes, and standard laboratory burn tests on polyethylene coupons. Also included was a burn test on the mitered end section with concrete apron. The evaluation focused on evaluating the fire risk from grass fires and does not consider other sources of fire such as vandalism or fuel spills. During the field burn tests, it was noted that the fire spread rapidly to the point where soil completely encased the pipe. At that point, the fire slowed to a steady circumferential flame. Typical in field burn specimens was a reduction in pipe wall thickness which [led] to soil falling into the pipe which helped to slow spread of the fire. The reduction in pipe wall thickness is obviously a major point of concern since the loss of material reduces the pipe['s] ability to carry load. Out of the 41 states responding to the study, only four reported incidents of fire and the total number of fires was reported as eight. With the number of fires reported and the total number of years of service of the HDPE pipes, the rate of fires is one fire per state every 48 years. Based on the results of this study, the overall risk of damage to HDPE pipes from fire is considered minimal. However, it was noted that mitered end sections of HDPE pipes are subject to fire damage and possible destruction when exposed to grass fires.
>
> A performance evaluation of HDPE pipes by the Materials and Tests Unit of the North Carolina Department of Transportation (1991) indicated that during a flammability test the double layer design of the pipe caused the fire to be constantly fueled throughout the length of the pipe. As the inner layer burned, the corrugations would melt and droop over the edge of the pipe, like a sheet, thus providing more burnable surface area. The flames would burn up the drooping sheet of plastic and eventually ignite the smooth wall interior. As the interior wall burned, it would melt the corrugation above it causing it to droop down into the pipe thus repeating the process across each corrugation. The pipe burned at an approximate rate of 1 ft per 20 minutes. The relative ease at which it caught fire and burned raised questions about its potential applications. Any application where the ends are exposed makes it susceptible to fire damage. Consequently, proper end protection is advised.

South Dakota

Evaluation of High Density Polyethylene (HDPE) Pipe, Anselem H. Rumpca, South Dakota Department of Transportation, April 1998.
http://www.sddot.com/business/research/projects/docs/SD9611FinalReport2.pdf
Researchers provided recommendations to allow the installation of HDPE pipe based on information gathered from a survey of state DOTs, a literature review, and the results of the first installation of HDPE pipe under a state highway in South Dakota. Findings from the state survey and literature review addressed the potential for damage by fire. *From page 43 of the report (page 49 of the PDF):*

> **Potential for Damage by Fire**
> The susceptibility of polyethylene pipe to fires is an important issue that has been addressed by various testing facilities including studies conducted in Florida and Texas. Texas DOT officials conducted ten different scenarios, testing two twenty foot sections of HDPE pipe. After attempting to ignite the pipe with combustible materials, Texas DOT engineers attending the test felt the polyethylene material was not a fire concern for culvert installations (24).
>
> A study performed by the Florida Department of Transportation concluded that “the heat gain of the pipe cross section was not sufficient to cause softening or subsequent weakening of the pipe during burn tests.” Out of the 41 states responding to the Florida study survey, only four reported incidents of fire and the total number of fires was reported as eight. The computed rate at which fires affecting HDPE pipe have occurred is one fire per state every 48 years. However, it should be noted that mitered polyethylene end sections are “... subject to fire damage and destruction when exposed to expected grass fire intensities.” The Florida DOT recommends that the polyethylene pipe terminate in a concrete headwall, drainage structure or non-plastic mitered end concrete apron (25).
>
> In November 1991 a routine fuel reduction burn destroyed 60 lineal feet of 760 mm (30 in) polyethylene pipe culvert in the Badlands National Park in South Dakota. While this event has been highly publicized, it remains an isolated incident. The author is not aware of any other fire causing damage to HDPE pipe in South Dakota.
>
> The South Dakota Department of Transportation uses an Approach Pipe Plan Note that specifies “Class II Reinforced Concrete Pipe with Safety Ends and Polyethylene Pipe with CMP end sections may be substituted for Corrugated Metal Pipe at approaches on a per site basis at no additional cost to the State. Acceptance of polyethylene pipe will be by certification. The end sections for the polyethylene pipe shall be metal and conform to the details for CMP end sections, and shall be compatible to the polyethylene pipe.” While the use of concrete or metal end sections is recommended for those areas where the possibility of grass fires exist, it is recommended that the SDDOT allow the option of using plastic end sections in municipal settings.

Texas

Pipe Selection, Texas Department of Transportation, August 2018.
http://ftp.dot.state.tx.us/pub/txdot-info/brg/txdot-pipe-selection-updated-07-27-18.pdf
This procedure addresses pipe types, selection criteria, selection responsibility, evaluation of new pipe culvert materials and restricted use of new pipe culverts. It does not provide recommended materials or actions for placing pipe in fire-prone areas.

2017 Polypropylene Survey Responses, AASHTO Committee on Construction, 2017.
https://construction.transportation.org/wp-content/uploads/sites/20/2017/04/2017-Polypropylene-Survey.xlsx
In July 2017, Oklahoma DOT conducted a survey to identify how other states approach the use of polypropylene pipe for cross drains or side drains. The survey results, published by the AASHTO Committee on Construction, include a response from Texas DOT that discusses protecting the ends of polypropylene pipe. *From the survey responses*:

> TxDOT allows polypropylene pipe, but when it is installed under a paved public roadway it has to serve as a culvert and the ends must be protected. That protection consists of non-flammable material of varying length depending on the pipe diameter. The non-flammable end sections can be made of corrugated metal pipe, reinforced concrete pipe or other material deemed acceptable by the DOT. The manufacturers have asked that we remove the end section requirements but we have not gone in that direction, nor do we plan to do so, given the risk of fire and consequent failure of the flammable pipe material. Several years ago TxDOT had a double-barrel HDPE pipe that caught on fire, disintegrated and collapsed, which led to the addition of the nonflammable end sections.

Related Resources

The resources below are organized into three categories:

- Research-related publications.
- ADS, Inc.
- Fire-protective or fire-retardant products.

Research-Related Publications

Fire Testing of High-Density Polyethylene Pipe, D. Munson, Electric Power Research Institute, August 2011.
Report available at https://www.epri.com/#/pages/product/1023004/
From the abstract: The results in this report are intended to demonstrate a method that can be used to protect high-density polyethylene (HDPE) piping located aboveground from postulated fire events. This includes protecting both pipe and pipe fittings (for example, elbows, tees and valves) from the fire environment—including the heat transmitted from pipe supports—and preventing the fire environment from passing through building wall or floor penetrations.

The report is intended to be complementary to other ongoing Electric Power Research Institute (EPRI) activities that have the overall objectives of qualifying HDPE piping for use in belowground and aboveground applications in safety-related and non-safety-related piping systems.
….

Approach
Four piping subassemblies were designed that contained many of the fittings and components commonly found in HDPE piping systems. They included a flanged joint, a tee, an HDPE valve, straight pipe, butt fusion joints, mitered elbows and pipe caps as well as rod hangers to provide deadweight support. The pipe, pipe fittings and components, and pipe supports were wrapped with an endothermic material that had previously been qualified for protecting cable trays and conduits from the fire event. The subassemblies were subject to both deadweight and pressure loads with the resulting stresses somewhat in excess of those allowed by ASME Code Case N-

755-1. They were installed in a furnace with fire-resistant packing material and a water-resistant sealant used at wall penetrations. The assemblies were subject to a 3-hour fire test according to the guidance of ASTM E119 followed by a hose stream test according to the guidance of ASTM E2226. The assemblies were monitored for leakage throughout the event, and thermocouples were used to measure the surface temperature of the piping assemblies.

Results
All four specimens survived the test, with each retaining its overall geometry, cross section and structural and pressure boundary integrity. The wall and ceiling penetrations held; no excessive heat was transmitted through the penetrations during the fire test, and no water was transmitted through the penetrations during the hose stream test. In addition, no damage to the pipe or significant cracking of the penetration seals was observed from the thermal shock and erosion force of the hose stream test. Although pipe surface temperatures exceeded the target temperature for three of the specimens, the actuator nut on the valve melted, and some permanent deformations of two of the assemblies were found, no water leaked from any of the assemblies. These conditions could likely be prevented with some improvements to the wrapping method for complex shapes and/or additional layers of the barrier material.

Related Resource:

> **"Fire Testing of High Density Polyethylene Piping Systems,"** Douglas Munson and Dana Decker, *ASME 2012 Pressure Vessels and Piping Conference*, Vol. 7, pages 159-168, July 2012.
> Citation at
> http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1726261
> *From the abstract:* Degradation of raw water piping systems is a major issue facing nuclear power plant owners. High density polyethylene (HDPE) is a cost-effective alternative to corrosion resistant alloys and has been found to perform well in power plant applications for over 10 years. When used above ground, fire resistance may be an issue. HDPE starts to melt at ~235°F (115°C) and has an auto-ignition temperature of ~662°F (350°C). Additionally, toxic gasses are released when it burns.
>
> The paper summarizes the development of a method that can be used to protect HDPE piping from postulated fire events i[n] situations where the system must remain operable or not contribute to the fire load. The method was demonstrated using a proof-of-concept fire test of four piping subassemblies that contained many of the fittings that are commonly found in HDPE piping systems. The assemblies were subject to a 3-hour fire test following the guidance of ASTM E119 followed by a hose stream test following the guidance of ASTM E2226. All four specimens survived the test, with each retaining its overall geometry, cross section, and structural and pressure boundary integrity.

Evaluation of HDPE and PVC Pipes Used for Cross-Drains in Highway Construction, Shepard Jefferson Stuart, Master's Thesis, Auburn University, 2011.
https://etd.auburn.edu/bitstream/handle/10415/2513/S_Stuart%28Final%29S.pdf?sequence=2&isAllowed=y
This master's thesis sought to assess the use of HDPE and PVC for use as cross-drains under highways and to assist Alabama DOT in developing a methodology for using plastic pipe. *From page 78 of the report (page 99 of the PDF)*:

2.14.4 Fire Resistance

While the risk of fire in sewer pipe systems is limited, there is a potential for fire to occur in or around culverts (Hancor 2009). The resistance to fire for culvert pipes is an important issue especially for exposed ends. Both HDPE and PVC pipes will burn when there is adequate air flow such as in culverts (Zhao et al. 1998). Pipes can be protected from fire with the use of inflammable end treatments such as the use of [r]ip-rap, gravel, or concrete headwalls around exposed ends (Hancor 2009). The National Fire Protection Association gives polyethylene a rating of 1 (slow burning) on a scale from 0 to 4, where higher rating indicates more vulnerability (Gabriel 2008).

Zhao et al. (1998) believe that physical resistance to fire plays an important role in the performance and durability of sewer and culvert pipes. Table 2-22 shows the physical resistance of various pipe types to abrasion and fire.

Table 2-22. Physical Resistance of Various Pipe Types (Zhao et al. 1998)

Type of Resistance	Pipe			
	Concrete	Corrugated Steel	HDPE	PVC
Abrasion resistance	Low	Low	High, 2 and 3 times more resistant than PVC and steel pipe, respectively	High
Fire resistance	High	Most coatings used for corrosion protection are flammable	Flammable	Flammable with lower flammability rating than HDPE
Freeze-thaw resistance	See note	—	—	—

Note: It is not certain whether concrete culvert pipe is subjected to freeze-thaw damage. Testing is required to clarify this.

According to Uni-Bell (2005), PVC pipes are difficult to ignite and will not continue to burn in the absence of an external ignition source. The temperature for spontaneous ignition of PVC is 850°F, which is much higher than most construction materials. PVC pipe is also referred to as a self-extinguishing material because the products of combustion combine with any available oxygen, thus starving the flame (Uni-Bell 2005).

HDPE deforms at temperatures above 120°C and begins to melt completely at 135°C (Zhao et al. 1998). The ignition temperature of HDPE is 660°F, which is lower than for PVC (Philbin and Vickery 1993). According to Zhao et al. (1998), a flammability test carried out by the North Carolina Department of Transportation in which one end of a corrugated HDPE culvert pipe was exposed to fire caused the pipe to be engulfed in flames within one minute. The pipe was then observed to fuel the fire and burn continuously throughout its entire length (Zhao et al. 1998).

In 1994, the Florida Department of Transportation (FDOT) conducted a study to determine the actual fire risk in typical HDPE pipe installations due to recent concerns expressed relative to the flammability of HDPE pipes (FDOT 1994). The study included field burn tests as well as standard laboratory burn tests on polyethylene coupons. The field tests also included burn tests on mitered end sections with concrete aprons. The results of the study indicated that HDPE pipe installed to present standards is not at significant risk of fire when exposed to fire such as that which would be encountered in a roadside grass fire (FDOT 1994). The report did however say that mitered polyethylene end sections are "… subject to fire damage and destruction when exposed to expected grass fire intensities" (FDOT 1994). The report recommends that the polyethylene pipe terminate in a concrete headwall, drainage structure, or non-plastic mitered end concrete apron (FDOT 1994).

In a South Dakota DOT report, Rumpca (1998) states that in November of 1991 there was a routine fuel reduction burn that destroyed 60 linear feet of 30 inch diameter polyethylene pipe culvert located in the Badlands National Park in South Dakota. The author states that even while highly publicized it was an isolated incident and to his knowledge there have been no other fires that have caused damage to HDPE pipe in South Dakota (Rumpca 1998).

In 1993, Philbin and Vickery wrote a report on the fire performance of HDPE pipe. The report cited past fires dealing with plastics and then explained a full-scale field test of a polyethylene pipe (Philbin and Vickery 1993). The field test consisted of a 30-inch diameter by 20-foot long pipe section installed as a drain culvert pipe with 24 inches of cover. The source of ignition was an ordinary, wood-stick-type kitchen match that was struck and held against the edge of the pipe. The pipe ignited within seconds and the flame began to extend upward. The pipe continued to burn until the pipe was destroyed (Philbin and Vickery 1993). Philbin and Vickery (1993) have recognized a fire hazard with HDPE and do not recommend that it be used in drain and sewer systems, because of the difficulty of fire control, confinement, and extinguishment.

In 1998, Gabriel and Moran conducted a survey of all 50 states with regards to durability issues of which 49 responded. The report stated that Colorado has experienced two cases of damage to HDPE pipes resulting from weed fires (Gabriel and Moran 1998). California reported that an uncontrolled Malibu fire destroyed unprotected HDPE (Gabriel and Moran 1998). The Florida DOT concluded that when exposed to grass fires, HDPE is not at significant risk. The Ohio DOT has used polyethylene pipe as cross drains with exposed ends under roadways since 1982 and has had no recorded incidents of fire. The state of Washington has had no record of fire related failures and believes that the risks associated with the flammability issue are essentially unjustified. New York reported that HDPE and PVC present no significant risk of damage by fire (Gabriel and Moran 1998). The report by Gabriel and Moran (1998) goes on to state that some states require noncombustible exposed ends for plastic pipe.

Related Resources:

Chapter 4-0, Durability, *ADS, Inc. Drainage Handbook*, ADS, Inc., November 2015.
https://www.ads-pipe.com/sites/default/files/Drainage_Handbook_ADH4_Durability_(11-15).pdf
From the overview: This section, while discussing corrosion, erosion and weathering effects [on pipe materials] on an individual basis, provides suggestions for appropriate materials when a multitude of durability factors are present.

Handbook of PVC Pipe: Design and Construction, Fifth Edition, Uni-Bell PVC Pipe Association, 2012.
https://www.uni-bell.org/Resources/Handbooks
From the web page: The Handbook provides practical engineering and construction information and includes recommendations applicable to the design and use of primarily underground PVC piping systems in both pressure and non-pressure applications.

Durability and Performance of Gravity Pipes: A State-of-the-Art Literature Review, Jack Q. Zhao, S. Kuraoka, T.H.W. Baker, P. Gu, J.-F. Masson, S. Boudreau and R. Brousseau, Institute for Research in Construction, National Research Council of Canada, 1998.
Publication available at http://publications.gc.ca/collections/collection_2013/cnrc-nrc/NR35-18-1998-eng.pdf
A discussion of fire resistance begins on page 28 of the report (page 35 of the PDF). The authors address the temperatures at which plastic pipe deforms and cite a 1991 North Carolina DOT study that concluded "any application where the ends of HDPE pipe are exposed, such as culvert applications, makes it susceptible to fire damage." The 1991 North Carolina DOT report, cited as Performance Evaluation of AASHTO M 294 Type "S" Polyethylene Pipe, does not appear to be publicly available.

Evaluation of High Density Polyethylene (HDPE) Pipe, Anselem H. Rumpca, South Dakota Department of Transportation, April 1998.
http://www.sddot.com/business/research/projects/docs/SD9611FinalReport2.pdf
Researchers provided recommendations to allow the installation of HDPE pipe based on information gathered from a survey of state DOTs, a literature review and the results of the first installation of HDPE pipe under a state highway in South Dakota. Findings from the state survey and literature review, which addressed the potential for damage by fire, are available on page 27 of this report.

NCHRP Synthesis Report 254: Service Life of Drainage Pipe, Lester Gabriel and Eric Moran, 1998.
Citation at http://www.trb.org/Main/Blurbs/154376.aspx
From the synthesis report description: The synthesis describes the current state of the practice regarding state transportation agency standards and strategies that determine and define the service life of drainage pipe. Information for the synthesis was collected by surveying state transportation agencies and by conducting a literature search. This report of the Transportation Research Board is an update of NCHRP Synthesis 50: Durability of Drainage Pipe (1978). The synthesis provides detail on the elements influencing material durability considered in the selection of drainage pipe. These elements include the definitions of useful service life and life expectancies of various types of pipe protection systems in differing environments based on such facts as pH, resistivity, abrasion, flow conditions, etc. Protection strategies that influence material durability are also addressed.

High Density Polyethylene Pipe Fire Risk Evaluation, Corrosion Research Laboratory, State Materials Office, Florida Department of Transportation, July 1994.
See Attachment C.
This report presents the results of a study of the flammability of HDPE pipe to determine the actual risk of fire in typical pipe installations. A brief summary of this study is available on page 17 of this report.

Chapter 6, Durability of Composites Exposed to Elevated Temperature and Fire, A.P. Mouritz, *Durability of Composites for Civil Structural Applications*, pages 98-125, 2007. Publisher summary available at https://doi.org/10.1533/9781845693565.1.98

From the publisher summary: An important durability property of polymer matrix composites when used in civil infrastructure is fire resistance. The composites most commonly used in infrastructure are reinforced with fiberglass due to its relatively low cost and high strength. The organic matrix to fiberglass composites is usually a polyester, vinyl ester or general-purpose epoxy, due to low cost and good mechanical properties. More expensive carbon fiber composites are used in exceptional circumstances, usually when high stiffness and fatigue endurance are required for the reinforcement of highly loaded bridge sections. An important consideration in the use of polymer composites is the threat of fire from arson, terrorist attack, accidents and natural events. The composites used in civil infrastructure pose an unusually high hazard because the polymers most often used are highly flammable and release copious amounts of heat, smoke and fumes when they smolder and burn. The need to use low-cost materials in many infrastructure applications precludes the use of expensive flame-retardant polymers or fire-protective coatings. Therefore, an appreciation by civil engineers of the fire properties of polymer composites is important in the safe design and durability assessment of structures.

ADS, Inc.

Chapter 4-0, Durability, *ADS, Inc. Drainage Handbook*, ADS, Inc., November 2015. https://www.ads-pipe.com/sites/default/files/Drainage_Handbook_ADH4_Durability_(11-15).pdf

See page 4-13 of the chapter (page 13 of the PDF) for a brief reference to the 1994 Florida DOT report (included in this Preliminary Investigation as Attachment C) and a recommendation for areas where flammability "is of extra concern":

> A report published by the Florida Department of Transportation entitled *High Density Polyethylene Pipe Fire Risk Evaluations* states "HDPE pipe is not at significant risk of fire when installed to present standards and exposed to fire such as that may be encountered in roadside grass fires."
>
> The natural gas industry has utilized polyethylene pipe, in diameters up to 18 in., for more than 30 years without reported problems. Polypropylene is commonly used for cold and hot water distribution lines, among other uses, and has seen growing use internationally for years. For areas where flammability is of extra concern, all pipe materials can be protected with the use of inflammable end treatments such as the use of [r]ip-rap, gravel or concrete headwalls around exposed ends.

Note: The following summarizes a January 9, 2019, conversation between Caltrans and ADS, Inc.:

It has been found that:

1. Coatings on thermoplastic pipe have been found to be ineffective as fire retardants. The ability for a coating to bond to the thermoplastic material is limited in durability. The coating will likely peel off, potentially causing chemical intrusion and impacting the water quality of the receiving water.
2. Admixtures and additive substances used with thermoplastic resins to make the thermoplastic pipe more "fire-retardant" can dramatically change the structural characteristics of the thermoplastic pipe and compromise its integrity.

Fire-Protective or Fire-Retardant Products

260183-1 Flamarest 1600 BTX, Catalyzed Epoxy Thermal Insulating Coating, OEM [original equipment manufacturer] Specification, Aerospace Coatings, AkzoNobel, undated.
https://aerospace.akzonobel.com/product/260183-1-flamarest-1600-btx
Headquartered in the Netherlands, AkzoNobel is described as “a leading global paints and coatings company and a major producer of specialty chemicals.” This web site describes Flamarest, which was developed to provide short-time fire protection, and has been evaluated and tested extensively for marine use on ships and boats. There is no indication that this product has been used in the culvert application of interest to Caltrans. *From the web site:*

> Flamarest 1600 BTX was developed to meet the requirement for a tough, durable intumescent interior and exterior epoxy coating. It is designed to respond quickly to provide short-time fire protection. This coating can be used in many industrial applications where other intumescent coatings cannot withstand the environmental exposure. It has been evaluated and tested extensively for marine use on ships and boats. The basic resin system/intumescent agents were developed for cook-off protection on Navy rocket launchers and the material has undergone extensive environmental testing. Polyester (fiberglass), various types of plastics, aluminum alloys, and steel are the most common substrates protected by Flamarest 1600 BTX. Virtually all field applications have been sprayed as this produces the best appearance at the lowest labor cost. Conventional air atomized spray equipment can be used to apply these high solids content coating systems. The three component catalyzed epoxy resin fuses into a tough porcelain-like shield that protects the substrate while providing a highly efficient thermal barrier against flame and heat. Most substrates can be protected in one application of 10-30 mils (254-762 microns). The cured film is beige in color.

Advanced Polymer Concretes and Compounds, First Edition, Oleg Figovsky and Dmitry Beilin, CRC Press, December 2013.
Book description at https://www.crcpress.com/Advanced-Polymer-Concretes-and-Compounds/Figovsky-Beilin/p/book/9781466590328
From the book description: The book covers a new type of epoxy composition with nano-heterogenic structure with potential for better mechanical properties and chemical resistance, acid-resistant building materials based on a nanostructured binder, and an advanced environmentally friendly and weather-resistant fire-protective coating for indoor and outdoor application to flammable substrates. With a focus on novel concretes and protective compounds for a variety of environments, this book reflects the newest developments in the rapidly growing field of building materials engineering.