Safer Alternative Graffiti Management Methods for California

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EXECUTIVE SUMMARY

Graffiti management and control is a resource intensive and costly problem for public agencies and private companies. Taggers use various materials like spray paint, marker, stickers and acid or diamond tipped tools to deface surfaces like sidewalks, masonry walls, fences, lamp posts, traffic signs, billboards, glass and plexiglass. Some of the methods used today for mitigating graffiti pose risks to workers and community members, lead to emissions of volatile organic compounds (VOCs) or cause other environmental damage. Alternative methods that are safer for workers and the environment are necessary.

This project was sponsored by U.S. EPA Region IX, the Bay Area Air Quality Management District (BAAQMD) and the San Francisco Department of the Environment (DE). The project was conducted by the Institute for Research and Technical Assistance (IRTA), a technical environmental nonprofit organization established in 1989. IRTA's mission is to find safer alternatives in industrial and consumer product applications, with a heavy focus on solvents. The purpose of this project is to identify, develop, test and demonstrate safer alternative graffiti management methods.

IRTA recruited several public agencies in Northern and Southern California to help identify graffiti control challenges and to focus on finding safer alternative methods of dealing with them. IRTA worked with the participating agencies to test alternatives in three specific categories. These include:

- Blasting systems
- Graffiti removers
- Protective films and graffiti resistant coatings

The results of this project are described below and they should be useful to other agencies and private companies throughout California and the rest of the country.

Blasting Systems

The blasting systems most commonly used today are sodium bicarbonate (or soda) blasting and high pressure water blasting. These systems generate a significant amount of waste material and most of California is subject to regulations requiring zero discharge to storm water. IRTA wanted to find and test alternative blasting methods that are more effective and minimize the generation of waste.

IRTA investigated and tested two alternative blasting systems. The first, dry ice blasting, eliminates the generation of secondary waste altogether and is most useful for removing light graffiti. The second, a system that relies on wet crushed recycled glass, generates much less waste than soda blasting and it is useful for removing heavy graffiti on a range of substrates. The waste from both technologies is significantly lower than for the currently used methods and it can be collected more easily and cost effectively.

The two technologies were demonstrated several times during the project and the combination of the two technologies is a good option for controlling graffiti on a range of surfaces. The crushed recycled glass system can remove graffiti much more effectively and faster than the soda blasting system. IRTA conducted a cost analysis and comparison of the soda blasting system on the one hand and the combination of the dry ice and crushed recycled glass systems on the other hand. The annualized costs of using the two options are comparable; the cost of using the soda blasting system is $11,656 and the cost of using the two alternative systems is $11,244.

Graffiti Removers

As part of the project, IRTA analyzed the characteristics of several commercial graffiti removers used by the participating agencies and listed by one of the sponsors, the San Francisco DE. Several of the graffiti removers used by participants contained toxic components like methylene chloride, a carcinogen, and N-methyl pyrrolidone, a reproductive and developmental toxin. Many of the removers also had high VOC content and exceeded the allowed state VOC limit for the products.

There is no single graffiti remover that can accomplish all tasks and generally, several graffiti removers are used, depending on the need. IRTA formulated five graffiti removers for different applications during the project. IRTA conducted testing of eight of the commercial graffiti removers listed by the DE and four of the IRTA formulated graffiti removers on several different substrates, including concrete, hard fiberglass, metal and a street sign, to determine and compare their capabilities. Different types of graffiti, including light and heavy spray paint, Sharpie and paint marker and postal stickers, were applied to the surfaces for the testing as appropriate. Two of the commercial graffiti removers and two of the IRTA formulated graffiti removers were effective in removing heavy spray paint from concrete. All of the commercial graffiti removers performed well in removing light spray paint from surfaces with one exception; this product was designed specifically to remove only marker. The four IRTA formulated graffiti removers were effective in removing heavy spray paint, marker and postal stickers from several substrates.

Protective Films and Graffiti Resistant Coatings

IRTA tested transparent sacrificial films, designed for one time use, for protecting glass and plexiglass from etching. IRTA also tested one graffiti resistant coating for protecting glass. Taggers do not realize the films or coating is on the surface so they etch the film or coating rather than the glass. The film can be replaced and the coating can be touched up.

IRTA tested two types of transparent non-sacrificial films and one graffiti resistant coating for protecting street signs. For one of the films, made by 3M, the graffiti stays on the surface of the film and can be removed easily with packaging tape or nonaggressive graffiti removers; postal stickers can be readily lifted off the film. The other film, called Vandal Guard, is less costly but aggressive graffiti removers must be used to remove the graffiti. In addition, use of this film violates the warranty for the street sign so it is most useful for other types of signage. The graffiti resistant coating is slightly more costly to use than the 3M film on street signs and the graffiti must be removed with more aggressive graffiti removers. Use of this coating also violates the sign warranty.

IRTA tested five graffiti resistant coatings on masonry surfaces and two of the coatings on a hard fiberglass surface. Three of the graffiti removers performed well on the concrete and granite surfaces and did not noticeably discolor the surface. In general, aggressive graffiti removers must be used to remove the graffiti from the coatings. The coatings are useful for protecting concrete and granite surfaces only in certain cases. There is no clear advantage to using the coatings on the hard fiberglass surface.

Summary of Findings

Table E-1 summarizes the general applications and the management options that were tested during the project and can be used for graffiti abatement. In some cases, several different management methods can be used to control the graffiti and the table presents some performance issues and a judgment, based on the project testing and findings, of whether certain technologies are a good option to use for the particular application.

Table E-1
Summary of Applications and Management Options

Application	Management Option	Performance
Graffiti Control on Masonry Substrates	Painting over	Unsightly
	Graffiti remover followed by high pressure water spray	Good option for some substrates
	Blasting system removal	Good option
	Graffiti resistant coating and graffiti remover	Good option on limited substrates
Graffiti Control on Street Signs	Non-sacrificial Films	Good option, may be warranty issues
	Graffiti resistant coating and graffiti remover	Warranty issues
	Sensitive surface graffiti remover	Depends on graffiti
Graffiti control on wood	Painting over	Good option
	Blasting systems	Less aggressive systems
Graffiti Control on Nonporous Surfaces	Graffiti remover	Good option
	Graffiti resistant coating and graffiti remover	Graffiti removal more difficult
	Painting over	Coating type may not match
Glass graffiti or etching	Sacrificial films	May protect against etching
	Graffiti resistant coating	May protect against etching
	Graffiti remover	Won't protect against etching

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I. Introduction and Background

Many cities and public entities are responsible for on-going graffiti removal from buildings, freeway overpasses, vehicles like buses and trains, bus benches, walls, glass, painted surfaces and fences. Other entities, like private companies and utilities, also struggle to manage and control the graffiti. Graffiti vandalism is widespread and spray paint and marker inks are routinely used on large and small surfaces made of masonry, wood, metal, plastic, glass, vinyl and other substrates. Graffiti management is an extremely costly process and public and private organizations spend millions of dollars each year to mitigate the problem. Many of the materials used in the management process contain volatile organic compounds (VOCs) that contribute to smog and toxic materials that pose a threat to workers and community members. Some technologies used in graffiti mitigation also may pollute the storm water and land.

Public and private organizations spend increasing amounts of resources each year to control and manage graffiti. One source estimates that some $12 billion dollars are spent each year in the U.S. Last year, the San Francisco Municipal Railway alone spent about $12.5 million to remove graffiti from its buses and streetcars. In Los Angeles, the L.A.'s Office of Community Beautification spends $7.7 million a year on graffiti removal to cover an estimated 32.8 million square feet of graffiti.

According to the U.S. Department of Labor statistics, there are 3.4 million workers employed in industries that may involve graffiti removal. In California, which accounts for at least 10 percent of U.S. employees, the number may be as high as 340,000 workers. These workers are routinely exposed to VOC and toxic solvents and to the endocrine disruptors and asthmagens that are commonly found in graffiti removers.

The California Air Resources Board (CARB) estimates that VOC emissions from consumer product graffiti removers amount to 0.188 tons per day or more than 137,000 pounds per year (CARB, 2005). Most large organizations, like cities and private companies, purchase most of their graffiti remover from suppliers in large quantities. Based on the fact that the City of San Francisco uses about 1,000 pounds of graffiti removers per year and that there are about 480 cities in California, the annual use of graffiti removers by cities in the state could be as high as 500,000 pounds per year. There are many other non-city graffiti removers used so the use and emissions of these hazardous materials in California may be more than one million pounds per year.

The Institute for Research and Technical Assistance (IRTA), a nonprofit organization, was established in 1989 to identify, develop, test and demonstrate safer alternatives in industrial and consumer product applications. IRTA's work has a heavy focus on solvent alternatives. IRTA staff have worked with hundreds of facilities and agencies in California to find, develop and evaluate safer alternative solvent based products and have been involved in demonstrations of new and emerging technologies.

IRTA received a grant from EPA Region IX to find and demonstrate safer alternative graffiti management methods. Two other organizations, the Bay Area Air Quality Management District (BAAQMD) and the San Francisco Department of the Environment (DE), contributed funding and support to the project. The results of the project are presented here.

1.1. Project Approach and Areas of Focus

In general, the first step in the project was to recruit public agencies to participate in the project. IRTA identified several agencies in Northern and Southern California that were interested in working on the project. The second step in the project was to meet with the participating agencies to discuss and observe the operations that would be the focus of the work. The third step was for IRTA and each of the agencies to identify problems and types of operations that they were interested in addressing. Some of the agencies had very specific tasks they were interested in addressing. In some cases, they were using graffiti removers that contained toxic components or did not comply with California air regulations. IRTA identified how those graffiti removers were used with the agency and worked on finding alternative methods of managing the task. In addition, some of the agencies were using certain management options that did not accomplish a particular task in the best way and they wanted to find other, more efficient ways of handling the task. IRTA also worked with them on this challenge. After seeing all the operations the agencies managed, it was obvious that certain problems were common to many or all agencies. IRTA tried to solve these common problems as well as the specific problems each of the agencies identified.

Table 1-1 shows the agencies participating in the project and some of graffiti management methods they were interested in pursuing. Over the course of the project, IRTA worked with these agencies to test various solutions to the challenges they face in controlling graffiti.

Table 1-1
Agencies Participating in Graffiti Management Alternatives Project

Agency	Graffiti Management Methods
Port of San Francisco	Blasting Systems Graffiti Resistant Coatings Films Graffiti Removers
Municipal Transportation Agency (MTA)-Trains	Graffiti Removers
Municipal Transportation Agency (MTA)-Structures	Blasting Systems Graffiti Resistant Coatings Films Graffiti Removers
San Francisco Department of Public Works (DPW)	Blasting Systems Films Graffiti Removers
San Francisco City Hall and Bill Graham Concert Center	Blasting Systems Graffiti Resistant Coatings Graffiti Removers
Simi Valley Department of Public Works (DPW)	Films Graffiti Removers

The Port of San Francisco is responsible for managing graffiti on vast lands in the San Francisco area that include parks, walkways, buildings, street signs, fences and piers. They are interested in alternative blasting systems that minimize the generation of waste materials. They are also interested in graffiti resistant coatings that can protect certain surfaces. They are interested in sacrificial and nonsacrificial

films that can be used to manage graffiti on glass, plexiglass and street signs. Finally, the Port, like all the other project participants, is interested in finding more effective, safer graffiti removers.

The MTA is responsible for graffiti removal from the underground trains. The policy currently is to paint over the outside of the trains with a paint approved for that use. The MTA is interested in finding alternative graffiti removers for removing graffiti and stickers from the inside surfaces of the trains.

The other MTA group IRTA worked with is responsible for maintaining the structures like buildings and kiosks for housing the entrances to the underground trains, the tunnels the trains move through and other buildings with signs and surfaces vulnerable to graffiti tagging. Like the Port, the MTA structures people are interested in alternative blasting systems, graffiti resistant coatings, films and alternative graffiti removers.

The San Francisco DPW is responsible for controlling the graffiti in the city on parking meters, sidewalks, street signs and walkways. They are interested in blasting systems that minimize the generation of waste materials, films for street signs and safer alternative graffiti removers.

The City Hall and Bill Graham Concert Hall are made of granite. The Bill Graham Concert Hall has a graffiti resistant coating on it and the contractor that maintains it is interested in alternative blasting systems, graffiti resistant coatings and alternative graffiti removers.

The Simi Valley DPW is responsible for controlling graffiti in the city of Simi Valley. They are interested in films for street signs and alternative graffiti removers.

Each of the agencies participating in the project had specific tasks they wanted to accomplish in a better way. Some of these include:

- removing graffiti from escalator handrail
- removing adhesive and sticker residue
- removing graffiti from bare street signs
- removing graffiti from fiberglass structure panels
- removing graffiti from plastic light fixtures
- removing spray paint from bare masonry surfaces
- removing spray paint from masonry surfaces covered with graffiti resistant coatings
- removing graffiti from glass and plexiglass
- preventing glass etching

The fourth step in the project was for IRTA to investigate alternative management methods that might be appropriate for solving some of the general and specific problems. The fifth step in the project was to test various alternative management methods with the participating agencies to see if they performed effectively. The sixth step was to analyze and compare the performance and cost of the alternatives to the currently used methods. The seventh step was to prepare the final report and outreach materials.

1.2. Alternatives Selection and Performance

Performance of the alternative management methods was evaluated on a case-by-case basis. In all instances, the agency personnel provided information on their requirements for the process and judged

the performance in terms of their needs. It was important that the alternatives perform as well as or better than the materials or technologies used currently. IRTA selected alternatives for testing and analysis only if they would offer an advantage and only if they were in compliance with existing state and local regulations.

1.3. Cost Analysis

IRTA performed cost analysis for the alternatives that were successfully tested with one or more of the project participants. Depending on the operation, the types of costs that were evaluated included:

- Capital cost
- Materials cost
- Labor cost
- Utilities cost
- Other related operation costs

These costs were evaluated and, in some cases, compared with the cost of the currently used management methods.

1.4. Report Organization

Section II of this report discusses and summarizes the different management methods IRTA focused on in light of the graffiti management problems the participating agencies identified. Section III of the report provides details on the characteristics, the results of the testing and the cost analysis of alternative blasting systems, one of the management methods important to the participating agencies. Section IV of the report focuses on alternative graffiti removers. It includes an analysis of some of the graffiti removers listed by the San Francisco DE and summarizes a testing procedure IRTA used to compare their performance with the performance of some graffiti removers formulated by IRTA. Section V of the report provides information on methods of protecting surfaces. One of the methods analyzed is films for protecting street signs, glass and plexiglass, a technology some of the participants wanted to pursue. Another technology several participants wanted to pursue is graffiti resistant coatings. IRTA conducted comparative tests of the coatings on various substrates and the section summarizes the results. Section VI of the report discusses several different graffiti management tasks identified by the participating agencies and focuses on some of the methods IRTA used to solve them. Finally, Section VII of the report presents the results and conclusions of the analysis and testing. Appendix A includes the Material Safety Data Sheets (MSDSs) for the graffiti removers that were tested in the course of the project. Appendix B presents the MSDSs for the graffiti resistant coatings that were tested during the project.

II. Graffiti Characterization and Graffiti Management Problems

At the beginning of the project, IRTA recruited several public agencies to participate in the project. The purpose was to work with the agencies to discuss and observe the types of graffiti that taggers use and the graffiti management problems that were important to each of them. After meeting with the participating agencies and understanding the challenges they face in their day-to-day graffiti activities, IRTA and each of the agencies defined areas the agencies and IRTA would focus on to find, develop, test and demonstrate safer alternatives. This section focuses on the types of graffiti used by taggers and the substrates they tag and then identifies the graffiti challenges IRTA worked on with the participating agencies.

2.1.Graffiti and Substrate Characterization

Perhaps the most common type of graffiti is spray paint. Taggers purchase or steal cans of spray paint from hardware and big box stores. The taggers want to use the spray paint as long as possible before it runs out so generally it is applied fairly lightly on as many substrates as possible. Spray paint is applied by taggers on a range of different surfaces including masonry like concrete, painted and unpainted stucco and granite, metal fences, street signs, lamp posts, waste cans, wood fences, buildings and billboards, fiberglass seats, panels on buses, trains and structures, and glass and plexiglass. All of the project participants find spray paint on most of the surfaces they encounter.

Virtually all of the spray paint in California is solventborne. The California Air Resources Board (CARB) regulates air emissions from aerosol coatings. The CARB aerosol coatings regulation regulates VOC content using a reactivity approach which sets limits for the atmospheric reactivity of materials. As long as suppliers use carrier materials that have relatively low atmospheric reactivity, they can meet the VOC standards. As a consequence, they do not formulate with water as the carrier and all of the aerosol coatings sold in California are solventborne. The types of aerosol coatings on the market are enamels, primers, primer/topcoat combinations and various other specialty coatings.

Another common type of graffiti is marker. There are two different types of markers, standard markers and paint markers. Paint markers as the name implies have a paint base. Other markers generally have a resin and, often, an alcohol based carrier solvent. Sharpie, for instance, indicates on their MSDS that they use ethyl alcohol as the carrier solvent.

Another type of graffiti that is widely used today is stickers. Postal stickers are especially popular with taggers. These stickers are available for free at most post offices and taggers often pick them up there. Postal stickers must be very durable to survive a variety of weather and physical insults and they have a durable adhesive and are difficult to remove once they adhere to a surface. Taggers write their message in pen, paint or marker on the stickers ahead of time and they stick them on the bus seat or street sign or other substrate as they pass by. It can all be done quickly. The postal stickers are difficult to remove and they may leave a residue after they come off. Taggers also use other types of stickers and sometimes these can be removed but they may also leave a residue which can be difficult to remove.

Although spray paint, markers and stickers are the most common types of graffiti, there are others as well. These would include food wastes of various kinds and ink from ballpoint pens. A common trend currently, and one that is very difficult to deal with, is glass or plexiglass etching. Taggers can purchase

or steal acid based formulations or diamond tipped tools that are designed to etch a pattern in glass at graphics supply stores. The etching defaces the glass and is unsightly.

2.2.Graffiti Management Strategies

Table 2-1 summarizes the graffiti management strategies that were defined during the project and the agencies that have an interest in finding better methods of dealing with them. All of the participating agencies use painting over various graffiti tagged surfaces on a routine basis. Several of the participating agencies, including the Port of San Francisco, MTA-Structures, the San Francisco DPW and the Bill Graham Concert Hall were interested in finding alternative blasting systems. Several of the agencies, including the Port of San Francisco, MTA-Structures, San Francisco DPW and Simi Valley DPW, were interested in finding methods of managing graffiti on street signs. Several of the participants, including the Port of San Francisco, MTA-Structures and the Bill Graham Concert Hall, were interested in graffiti resistant coatings. Finally, all of the participants were interested in finding alternative graffiti removers. Each of these is discussed below.

Table 2-1
Graffiti Management Strategies/Problems

Strategy or Graffiti Problem	Agencies Interested in Solutions
Painting Over	All participating agencies
Blasting Systems	Port of San Francisco MTA-Structures San Francisco DPW Bill Graham Concert Hall
Graffiti Removers	All participating agencies
Graffiti Resistant Coatings	Port of San Francisco MTA-Structures Bill Graham Concert Hall
Street Sign Graffiti	Port of San Francisco MTA-Structures San Francisco DPW Simi Valley DPW

2.2.1.Painting Over

As indicated in Table 2-1, all of the agencies participating in the project paint over a significant portion of their graffiti. In fact, this is a very common practice and it is used routinely by virtually every agency or private company responsible for graffiti management.

Painting over is often the best option depending on the substrate that has been tagged and whether or not the tagging needs to be covered quickly. For instance, smooth substrates made of materials like metal or wood that are painted one uniform color can be painted over to mask the graffiti tagging routinely. In some cases, where there is strong gang activity, the tagging needs to be painted over quickly to prevent rival gangs from starting a tagging war.

At the beginning of this project, IRTA planned to investigate painting over and investigated the circumstances of the practice. IRTA had suspected that the paints used for painting over may have high

VOC content and that alternative paints with low VOC content might be used instead. It turns out that the system that is in place for painting over is a good one. Used paint is collected and recycled. It is virtually always low VOC material and the suppliers of the recycled paint can blend it to match any color that is needed for matching the paint on the substrate. Because painting over is handled well, IRTA decided not to investigate safer alternatives for this process.

Figure 2-1 shows a contractor for a large utility painting over a metal door at an electrical generating station. The paint has been color blended to be a good match for the paint on the door. Painting over is likely to be the best option in this case. Figure 2-2 shows a utility box on which the graffiti has been painted over by public works employees. In this case, the utility box was originally powder coated which gives a rich look to the finish. The paint applied by the public works employee is a glossy paint that matches the color but not the texture of the paint and it ends up looking unsightly. In this case, it is probably better to try to remove the graffiti with a graffiti remover; if that were not successful, painting over with a paint having a matte finish would be an acceptable option.

Figure 2-1. Contractor painting over metal door

Figure 2-2. Painted over utility box

Figure 2-3 shows a painted wooden fence on the property of the Port of San Francisco. The fence is covered with graffiti. Probably the best method for mitigating the graffiti in this case is to paint over the fence with low-VOC recycled paint that has been color matched. Painting over unpainted porous substrates like concrete and other masonry materials is probably not the best option because generally, the painted over portion of the wall does not look natural. In these cases, it would probably be better to maintain the integrity of the unpainted surface and use a graffiti remover to remove the graffiti. As discussed later, another option would be to use a blasting system or a graffiti resistant coating with a graffiti remover.

Figure 2-3. Graffiti on wooden fence at Port

2.2.2.Blasting Systems

As indicated in Table 2-1, many of the project participants either use or are interested in using blasting systems. The blasting systems used today for routine graffiti removal from a variety of surfaces, particularly masonry surfaces, are sodium bicarbonate blasting, referred to as soda blasting, and water blasting using pressure washers. Pressure washers are generally used in conjunction with graffiti removers because the water alone usually cannot remove graffiti very effectively. Both of these systems generate a large volume of waste material and this is their disadvantage.

Regulations in California for storm water require zero discharge. In some cases, where the waste materials go through a Publicly Owned Treatment Works (POTW) where the effluent is treated, discharge may be allowed. In nearly all parts of California, however, this is not the case so the zero discharge limit applies. In this instance, the waste materials from the use of the soda blasting system and the pressure washer must be collected and disposed of properly. The waste materials also must not be disposed of on the land unless the user conducts an aquatic toxicity test on the effluent to determine if it should be classified as hazardous waste in California. If it is classified as RCRA hazardous waste or California only hazardous waste, then it must be collected, handled and disposed of appropriately.

Many companies sell soda blasting systems and they are used widely. A picture of a contractor using a soda blasting system to remove graffiti from a building is shown in Figure 2-4. Note that the waste materials are deposited on the ground. The system is shown in Figure 2-5. Many companies sell

pressure washers and they can also be purchased at home improvement stores. A picture of a city worker using a pressure washer to remove graffiti from a sidewalk is shown in Figure 2-6. Note that the waste material is being flushed into the sewer. A picture of a painter using a pressure washer for removing graffiti from concrete is shown in Figure 2-7. Note that in this case, the effluent is being collected for later disposal.

Figure 2-4. Contractor using soda blasting system


Figure 2-5. Soda blasting system

As part of the project, IRTA investigated alternative blasting systems that would eliminate or minimize the generation of waste materials. The two systems IRTA examined and tested are a dry ice blasting system which generates no secondary waste and a crushed recycled glass blasting system which generates relatively low volumes of waste material. These systems are discussed in more detail in the next section.

Figure 2-6. City worker using pressure washer

2.2.3.Graffiti Removers

All of the project participants in Table 2-1 use graffiti removers routinely for removing graffiti from a variety of substrates. Many of the graffiti removers used today contain toxic ingredients and many have high VOC content. Two types of graffiti removers are used widely, aerosol and nonaerosol products. The aerosol products contain an aerosol propellant in addition to the graffiti remover. The nonaerosol graffiti removers can take many forms. Some of them are sold in spray bottles and some have a spray attachment. Other graffiti removers are sold as premoistened wipes in various types of dispensers or as gels.

Some of the graffiti removers used by the project participants contain toxic ingredients like methylene chloride, which is a carcinogen, or N-methyl pyrrolidone (NMP), which is a reproductive and developmental toxin. Although these materials are effective graffiti removers for certain applications, they should not be used because they pose a high risk to workers using them and to the people working or living in communities surrounding the source.

A picture of one of the Port of San Francisco staff using a graffiti remover is shown in Figure 2-7; he is removing graffiti from a plexiglass cover on a wooden billboard. Figure 2-8 shows a city worker with a scrub pad about to remove graffiti from a parking meter after he has applied a graffiti remover. Note that the workers are exposed to the components of the graffiti removers as they use them, often on a daily basis.

In California, the California Air Resources Board regulates the VOC content of graffiti removers. Aerosol removers must meet a limit of 50% VOC content or less and nonaerosol removers must meet a limit of 30% (CARB, 2012). These limits are not very stringent but even so, many of the graffiti removers sold and used in the state do not meet these limits.

Figure 2-7. Port staff using graffiti remover on plexiglass

Figure 2-8. City worker removing graffiti from parking meter

As part of the project, IRTA evaluated the graffiti removers used by the project participants and some graffiti removers listed by the San Francisco DE, one of the project sponsors. IRTA examined the MSDSs of the graffiti removers and, in many cases, called the suppliers to discuss the ingredients. Some of the graffiti removers contain toxic components and some do not meet the CARB VOC limits for graffiti removers sold in the state. Also as part of the project, IRTA conducted testing of a number of the San Francisco DE listed graffiti removers to determine their effectiveness for removing graffiti. This testing is described in Section IV.

Many of the project participants had specific graffiti problems they needed to solve. In some cases, they were using graffiti removers that contain toxic components and/or do not comply with the VOC limits set for graffiti removers in California. IRTA formulated several graffiti removers in the course of the project to solve these graffiti challenges and tested them with the project participants. IRTA's formulated products contain materials that are low in toxicity and most of them were formulated to have zero VOC content. These tests are also described in Section IV.

2.2.4.Graffiti Resistant Coatings for Protecting Substrates

There are many coatings that are marketed as anti-graffiti coatings. The term is misleading, however, and taggers do put graffiti on these coatings. The graffiti has to be removed with a graffiti remover. As part of the project, IRTA investigated the feasibility and cost of using these coatings for protecting surfaces.

There are a variety of graffiti resistant coatings that can be applied to a range of different substrate types including metal, glass, masonry and street signs. Some of these are waterborne coatings and some have solvent carriers which may also have toxicity problems. Many of the coatings offered by suppliers do not comply with the VOC regulations in California. In the case of these coatings, they must meet the VOC limits established by the local air districts. These limits differ depending on the air district but all the limits are relatively low compared with the limits, if there are any, in other parts of the country. IRTA tested five different graffiti resistant coatings representing four different types of coatings during the project.

One of the project participants, the Bill Graham Concert Hall, has a graffiti resistant coating on the building. A picture of the building with the graffiti resistant coating is shown in Figure 2-9. The issue is that, when the contractor removes graffiti from the coating, there remains a shadow. It was not clear if this was a result of the coating or the graffiti remover or both. Other users had also told IRTA that shadowing was a problem with these types of coatings and since several of the other participants were interested in the graffiti resistant coatings, IRTA wanted to investigate them further. IRTA resolved the issue by testing the coating from the Bill Graham Concert Hall and the four others on various substrates. Two of the coatings, both of which are waterborne, performed well in the testing. The tests and the results are described later in Section V.

Figure 2-9. Building with graffiti resistant coating showing shadowing

IRTA also tested one of the coatings for protecting street signs. It performed well in this application and the results are discussed in Section V.

2.2.5.Films for Protecting Substrates

There are two types of films that can be used to protect substrates. These include sacrificial films which are used only one time; they are pulled off when they are tagged and they are replaced with a new film. They also include non-sacrificial films which are permanent. With these films, the graffiti is removed from the film and the film remains in place over a long period of time.

Many agencies use sacrificial films on a routine basis. The MTA-Train people use these films on the train windows. When they are tagged, they are torn down and replaced with a new film. The sacrificial films are well established and IRTA did investigate them but only in a limited way. The testing results are described in Section V.

IRTA devoted much more investigation to non-sacrificial films which are most useful for protecting street signs. IRTA obtained two different types of non-sacrificial films and conducted extensive testing on street signs. Street signs are often tagged with graffiti and the graffiti is difficult to remove with most graffiti removers. The ink on the signs is often removed when graffiti removers are applied and particularly when scrubbing is necessary. A tagged street sign is shown in Figure 2-10.

Figure 2-10. Street sign with graffiti

Several of the project participants must mitigate graffiti on street signs. The Port of San Francisco, the San Francisco DPW, the MTAi-Structures group and the Simi Valley DPW all have street signs they must monitor on a regular basis. Other non-participants, like Cal Trans, for example, are also responsible for controlling graffiti on street signs. It is an important category and Section V of this document describes the non-sacrificial film testing on street signs in much more detail.

III. Alternative Blasting Systems

The commonly used blasting systems for removing graffiti are pressure washing with water and blasting with sodium bicarbonate media. Sodium bicarbonate blasting is often referred to as soda blasting since sodium bicarbonate is soda. Both of these technologies generate large quantities of waste and that is a major disadvantage of using them in California. As part of this project, IRTA investigated other blasting systems that would be effective and would generate no or minimal quantities of secondary waste from the technology itself. The alternative technologies IRTA evaluated, tested and demonstrated with the project participants include dry ice blasting and crushed recycled glass blasting. Each of these technologies is discussed below.

3.1.Dry Ice Blasting System Background

IRTA has tested dry ice blasting in other projects and has found it to be effective in a range of different applications. IRTA tested the technology for cleaning energized electrical equipment as a replacement for ozone depleting and global warming compounds. In particular, IRTA tested it for cleaning energized transformers at electric utilities and it performed well in this application. IRTA also tested it for stripping a copper antifouling coating from a boat hull. Although it did perform effectively in this application, a very large compressor was needed for stripping the old cured paint. IRTA was interested in testing dry ice blasting for graffiti removal because it was effective in other applications and because it does not generate any secondary waste.

The dry ice blasting process uses solid carbon dioxide as the media at high velocities. The unique feature of dry ice is that it sublimates or sublimes upon impact. This means it converts from a solid to a gas, so no secondary media is generated. The only waste from the operation is the material that was removed during blasting. Blasting with carbon dioxide has certain advantages. It does not leave a residue and it is a dry process, so it is not corrosive or conductive (this is why it can be used for cleaning energized electrical equipment). It does not etch or profile (leave a rough surface on) most metals and the carbon dioxide used in the process is recycled; it is taken from processes where it would otherwise be emitted. Processes that generate carbon dioxide as a byproduct are ammonia, nitrogen and natural gas production. The carbon dioxide from these processes is pressurized and refrigerated until it becomes a liquid. The extreme cold causes the liquid to solidify into a snow-like consistency. The snow-like solid carbon dioxide is compressed into either small pellets or larger blocks of dry ice.

A variety of industrial companies offer 3 mm high density dry ice which they can deliver to a central location or a job site. It is generally delivered in an insulated container. The dry ice can last seven to 10 days, depending on the application. Five to 10 percent sublimates each day and it gradually softens.

Dry ice is a comparatively soft material. On the Mohs scale of hardness, where talc is set at 1 and diamond is set at 10, dry ice has a hardness of 2. As a result, it is a gentle media. Dry ice blasting relies on three effects. The first is the pellet kinetic effect; because the dry ice particles have little hardness, it is important to use high velocity to blast it. The second is the thermal shock effect which is a surface effect only. A temperature gradient is established between the contaminant and the surface. The contaminant is colder than the surface so it shrinks and debonds from the surface. The third is the gas expansion effect. When the dry ice converts from a solid to a gas, its volume expands 800 times so it can pull the contaminant from the substrate from the inside out.

Systems for using dry ice are available in a variety of configurations for different types of applications. Cold Jet, one company that offers systems for users, has systems that range from 30 to 300 psi velocity, one to seven pounds per minute feed rate for the dry ice and more than 50 different nozzles to customize the delivery for the application. The systems are portable and require compressed air which can be supplied with a portable compressor or a stationary compressor. A picture of a typical system is shown in Figure 3-1.

Figure 3-1. Cold Jet system

3.2.Crushed Recycled Glass System Background

Crushed recycled glass was introduced into the market fairly recently so it is a relatively new media. The most common application for this technology is coatings removal and the media can effectively remove coatings from a range of substrates, including aluminum, steel, plastic, rubber, fiberglass and glass. It is also used for graffiti removal and historic restoration of stone and wood surfaces.

Crushed recycled glass is made from recycled bottle glass which is known as amorphous silica. It has less than one percent free silica which is commonly found in blasting sand. It is also free of heavy metals like arsenic, lead and beryllium which are typically found in coal and mineral slag. Crushed glass blasting results in very low particle embedment which produces a whiter, cleaner finish. The recycled bottle glass is manufactured in such a way that it is not sharp on the skin; if a worker places a hand in the bag and moves it around, it will not cut the skin. The media is generally used in a Farrow System and it is used wet in a slurry. Heat is added to the process to speed the removal. A picture of a typical system is shown in Figure 3-2.

3.3.Dry Ice Blasting and Crushed Recycled Glass System Testing

During the project, IRTA conducted testing with the two systems. Cold Jet provided their systems at four different times during the project to demonstrate their capabilities for the project participants. During the first demonstration, the systems were taken to Agua Vista Park in San Francisco and several of the project participants attended. Figure 3-3 shows the system removing graffiti from a lamppost and figure 3-4 shows the system removing graffiti from a picnic table.

Figure 3-2. Typical Farrow System

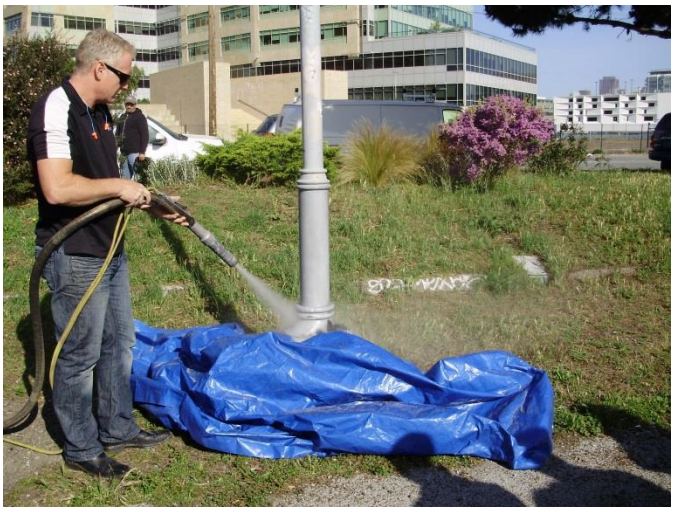

Figure 3-3. Blasting system removing graffiti from lamppost

Figure 3-4. Blasting system removing graffiti from picnic table

During the second demonstration, the systems were used to remove graffiti from a small walking pier and walkway on the Embarcedaro in San Francisco. A picture of the walking pier is shown in Figure 3-5. It includes molded seats and railings which are targets of taggers. The dry ice blasting system was used to remove the graffiti on these substrates and it worked well as shown in Figures 3-6 and 3-7. This system was also used to remove graffiti from the post structural components at the entrance to the pier. This is shown in Figures 3-8 and 3-9. The crushed recycled glass system is much more aggressive and this was demonstrated on the concrete walkway. Figures 3-10 and 3-11 show the system removing very old faded spray paint that could not be entirely removed previously being removed completely by the system. Figure 3-12 shows the system removing graffiti from the railing along the walkway and Figures 3-13 through 3-15 show graffiti, including sticker, removal from a post.

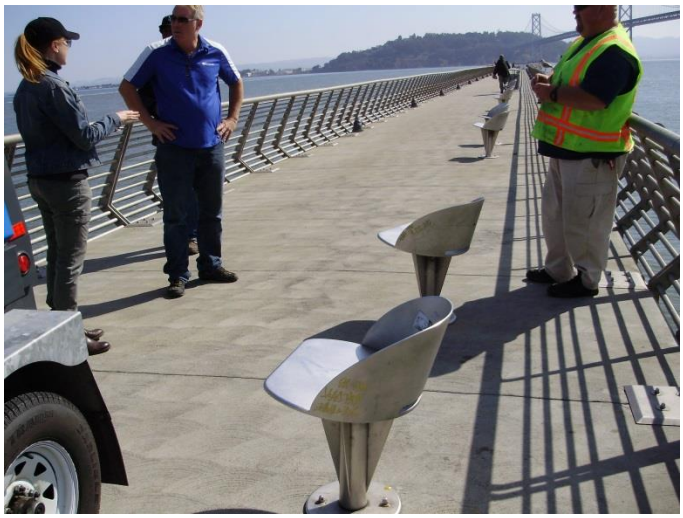

Figure 3-5. Port walking Pier

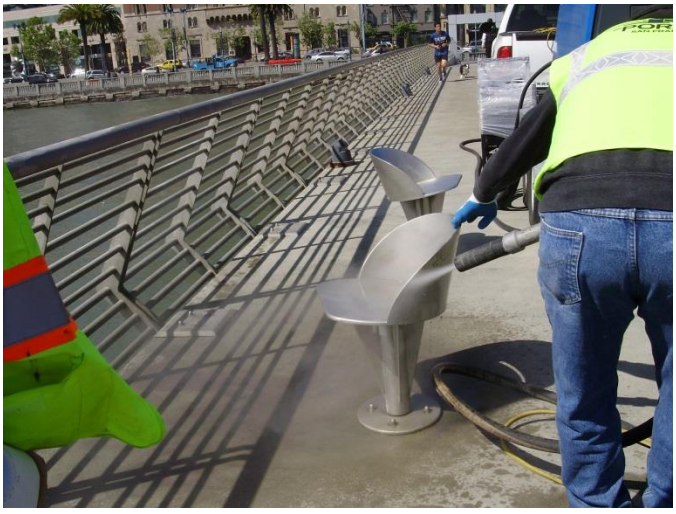

Figure 3-6. Dry ice blasting system removing graffiti from molded seats

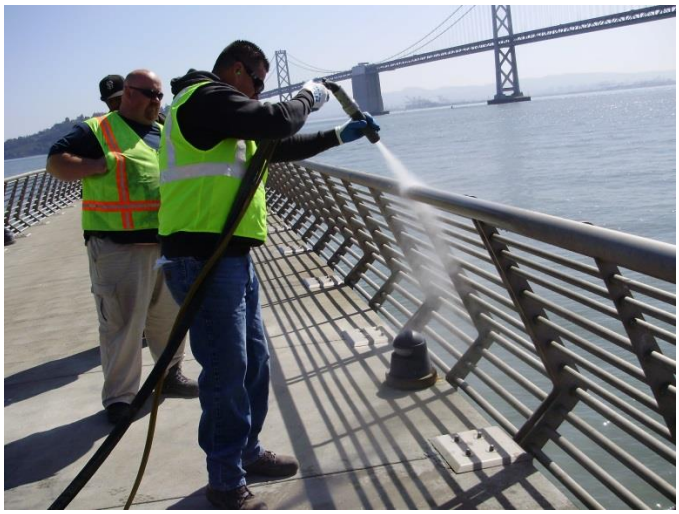

Figure 3-7. Dry ice blasting system removing graffiti from railings

Figure 3-8. Dry ice blasting system removing graffiti from post

Figure 3-9. Dry ice blasting system removing spray paint from post

Figure 3-10. Glass blasting system removing spray paint from divider

Figure 3-11. Glass blasting system removing spray paint from walkway

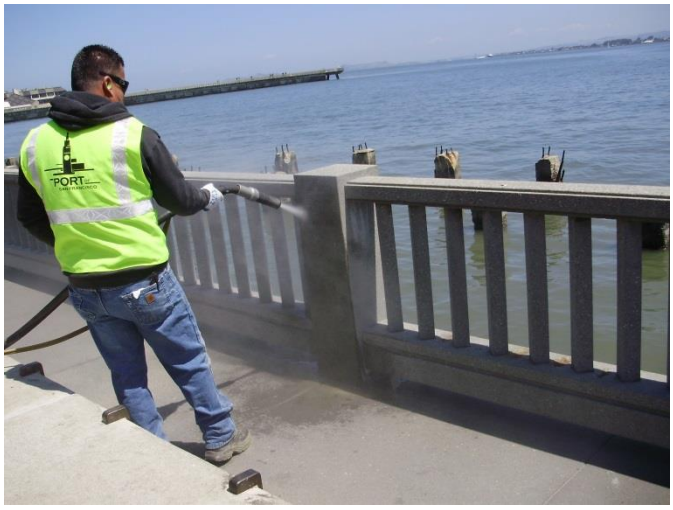

Figure 3-12. Glass blasting system removing spray paint from railing

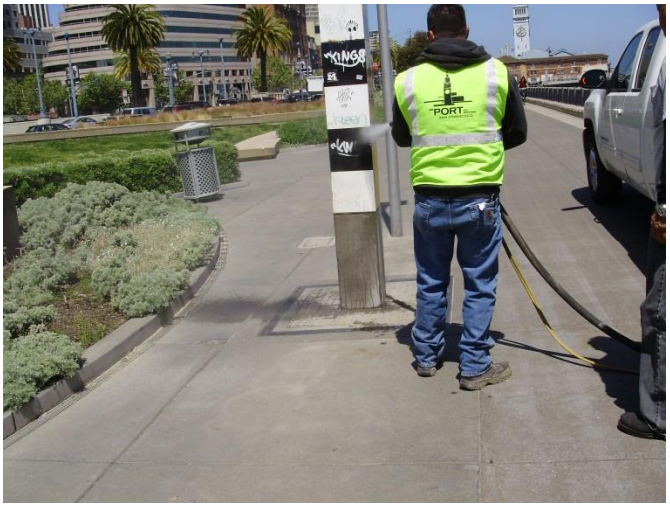

Figure 3-13. Glass blasting system removing spray paint from pole

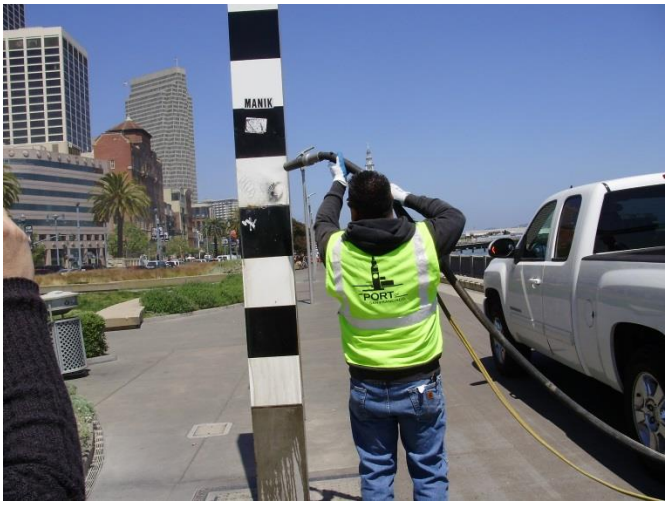

Figure 3-14. Glass blasting system removing graffiti from pole

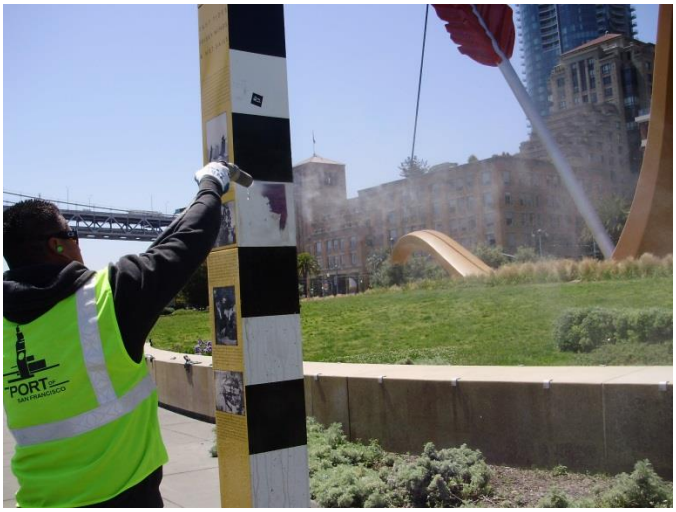

Figure 3-15. Glass blasting system removing sticker from pole

EPA held a press conference to feature the graffiti project and the systems were demonstrated once again at Agua Vista Park for this event. Figure 3-16 shows the dry ice blasting system removing graffiti from the posts of an old wooden pier. Figure 3-17 shows the system removing graffiti from a billboard with a plexiglass covering.

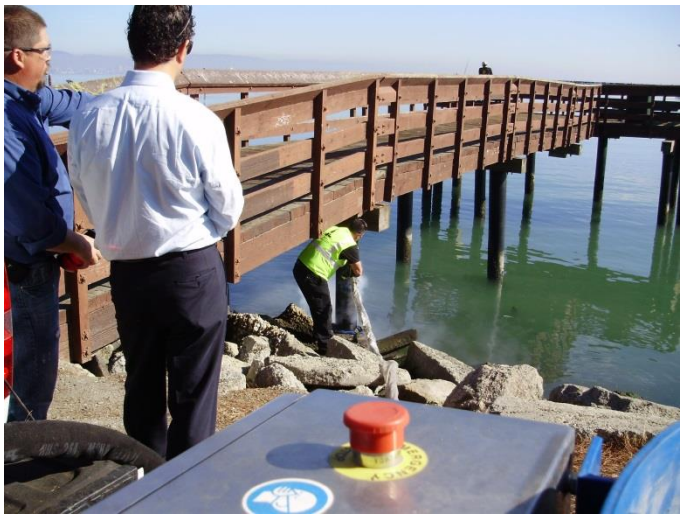

Figure 3-16. Dry ice blasting system removing graffiti from pier

Figure 3-17. Dry ice blasting system removing graffiti from billboard

EPA held another press event at Simi Valley in Southern California where the two systems were demonstrated. Figure 3-18 shows the dry ice system removing paint from a concrete barrier and Figure 3-19 shows the system removing graffiti from a metal component. Figure 3-20 shows the crushed recycled glass system removing graffiti from the concrete wall and Figure 3-21 shows the system removing graffiti from a metal transformer box.

Figure 3-18. Dry ice blasting system removing paint from concrete barrier

Figure 3-19. Dry ice blasting system removing graffiti from metal component

Figure 3-20. Glass blasting system removing paint from concrete wall

Figure 3-21. Glass blasting system removing graffiti from metal box

3.4.Cost of Blasting Systems

The Port of San Francisco and other agencies responsible for managing graffiti on a variety of substrates across large areas could consider purchasing a Cold Jet dry ice blasting system and a Farrow System using wet crushed recycled glass media. The combination of these two systems could accomplish virtually any graffiti removal task encountered. The dry ice blasting system, where the media is less aggressive, can blast light graffiti from many surfaces with minimal waste generation. The crushed recycled glass used in the Farrow system can blast difficult to remove graffiti from many surfaces like masonry, metal and fiberglass. Although the wet crushed recycled glass does generate waste material, it is minimal compared with more traditional dry media blasting which generates large volumes of waste. The soda blasting system , which is used by many agencies for removing graffiti, generates large volumes of waste. Other disadvantages of the soda blasting system are that it generates a significant amount of dust which air agencies might want contained and it kills vegetation because of the pH of the media.

3.4.1.Cost of Using Dry Ice Blasting

For dry ice blasting of graffiti, a user could purchase the Aero 40 system. It includes a blast hose and an air hose, a package including a variety of nozzles and an insulated hopper. The blast pressure of this system is 20 to 140 psi, the feed rate varies from zero to four pounds per minute and the hopper holds 40 pounds of dry ice. The cost of this system is $22,950. The system requires access to electrical or, alternatively, the user can purchase a small portable propane powered electric generator; one propane tank will last for approximately two days.

The capital cost of the system can be amortized over its life. Assuming the system has a life of ten years, and assuming a cost of capital of 4%, the annualized cost of the system would be $2,387.

The cost of the dry ice media for the system is about 24 cents per pound. On this basis, a 500 pound tote of dry ice which would provide six to eight hours of blast time hast a cost of $120. Assuming the system would be used for about eight hours over a one month period, the cost of the media in a year would amount to $1,440.

Another operating cost would be collection and disposal of the waste material. In this case, since very little is generated, it was assumed that this cost is negligible.

3.4.2.Cost of Using Crushed Recycled Glass Blasting

A user could purchase a portable Farrow system for about $23,950. The system would have to be hooked up to a compressor. A typical 185 cfm compressor, which would be appropriate for use with the system, would cost $10,000 to $12,000. Assuming the midpoint cost for the compressor, the total capital cost for this system would amount to $34,950. Assuming a 10 year life for the system and a cost of capital of 4%, the annualized cost for purchasing the system and compressor would amount to $3,635.

The operating cost includes the purchase of the crushed glass media. The cost of the media is $10 to $15 for a 50 pound bag. The blast time for a 50 pound load is about one hour at a cost of $12.50, assuming the midpoint of the cost for the media. Assuming the system is used for eight hours per month, the media cost would amount to $100. For a year, the media cost would be $1,200.

This system requires access to water. The water tank included with the system holds 30 gallons of water which will last for about two hours of blasting time.

Although a small amount of the media would be emitted during the operations, since the media is wet, IRTA assumed that all of the spent media would be collected with a tarp and that all that is used would require disposal. It is unlikely that the spent media would be classified as RCRA hazardous waste but it could be. Because IRTA did not sample the spent material, two scenarios were analyzed, one where the waste is RCRA hazardous waste and one where it is California only (non-RCRA) hazardous waste.

One supplier estimates that if the waste material is RCRA hazardous waste, the cost of disposal would be between $150 and $175 per drum. IRTA assumed the midpoint of the range or $162.50 per drum. If the waste material were non-RCRA waste but considered hazardous waste under California regulations, the cost would be lower, at $125 per drum. A five gallon bucket contains about one bag or 50 pounds of media. Annual usage is 4,800 pounds. On this basis, the user would generate about nine drums of waste material. The disposal cost would amount to $1,463 if the material is RCRA hazardous waste or $1,125 if the material is non-RCRA hazardous waste. The waste can be accumulated for 90 days. The hauler will charge a transport fee of $185 each time the waste is picked up. Assuming four pickups per year, the cost will be $740 per year. The hauler also adds a surcharge of 17 percent to the cost. On this basis, the total annual cost of disposal for RCRA and non-RCRA waste is $2,578 or $2,182 respectively.

3.4.3.Cost of Using Sodium Bicarbonate Blasting System

The cost of an industrial soda blasting system is about $10,000 which is lower in cost than the other two alternative systems discussed above. A 185 cfm compressor similar to the compressor for the crushed recycled glass system would also be necessary at a cost of $11,000. The total capital cost of the system would amount to $21,000. Assuming a cost of capital of 4% and a 10 year life for the system, the annualized cost of the purchases would be $2,184.

The sodium bicarbonate consumption rate for graffiti removal would be about the same as that for the crushed glass, one bag per hour. The cost of the sodium bicarbonate is higher than the cost of crushed glass, at $26 to $28 per 50 pound bag. The sodium bicarbonate has a hardness of 2.5 on the Mohs scale

which can be compared with the hardness of 6 for crushed glass. Because the soda media is not as hard, it would take more blasting time to accomplish the same task for the glass. Assuming the time required would be twice as long, the blasting time for this system would be 16 hours per month or 192 hours per year. Assuming a cost for the bicarbonate material of $27 per bag, the annual cost of purchasing media would be $5,184.

The disposal costs for the sodium bicarbonate spent media are the same as for the crushed recycled glass except that more waste is generated. The amount of waste that is generated, in this case, is 9,600 pounds which would fit in about 18 drums. Making the same cost assumptions as before for the crushed glass, the disposal cost for this material would amount to $4,288 or $3,498 for RCRA and non-RCRA waste respectively.

3.4.4.Cost Comparison of Systems

Table 3-1 summarizes and compares the annual cost of using the crushed recycled blasting system and the dry ice blasting system on the one hand with the cost of using the sodium bicarbonate blasting system on the other hand. The values show that the cost of using the two different systems is roughly comparable.

Table 3-1
Annual Cost Comparison of Blasting Systems

Cost	Crushed Recycled Glass/Dry Ice	Sodium Bicarbonate
Capital Cost	$6,022	$2,184
Media Cost	$2,640	$5,184
Waste Disposal (non-RCRA)	$2,178	$3,498
Waste Disposal (RCRA)	$2,582	$4,288
Total (non-RCRA waste)	$10,840	$10,866
Total (RCRA waste)	$11,244	$11,656

The values of Table 3-1 should be qualified by what was considered in the analysis. A full analysis would include several additional variables that could increase or reduce the cost of using either of the comparative technologies. Some of these variables and the influence they could have on the results are discussed below.

IRTA did not include the labor cost in the estimates in Table 3-1. The labor hours for the crushed recycled glass system are half the labor hours used for the sodium bicarbonate blasting system. The dry ice blasting system would be used together with the recycled glass system so the total hours would be higher than for the recycled glass system alone. It would depend on the user's applications as to whether the total hours would be the same or lower with the combined system. The labor cost is likely to be a large component of the total costs but, because it may vary greatly, IRTA did not make estimates of the cost here.

In practice, if the user had both the crushed recycled glass and the dry ice blasting systems, some of the work that would be done with the bicarbonate blasting system could be accomplished by the dry ice blasting system. In this case, because the cost of using the dry ice blasting system is much lower than the cost of using the soda blasting system, the costs for using the combined systems would be lower than presented here. On the other hand, the waste disposal costs for the sodium bicarbonate system

may be lower in practice because some of the dry media would be emitted. Again, however, air agencies could require users to shroud the blasting which would raise the cost of using this option significantly.

In many cases, users rely on both the soda blasting system and high pressure water system to remove graffiti. When removing graffiti with the water blasting system, a graffiti remover is generally applied before the blasting operation. The water blasting system generates a large volume of liquid waste which should be collected and not released to the storm drain. IRTA did not include the cost of using the water blasting system in the analysis and, if it were included, it would likely increase the cost of using the combined system above the cost of using the dry ice and crushed recycled glass system.

Many companies use sodium bicarbonate and water blasting systems today and virtually all of them do not collect the media. In nearly all parts of California, it is simply not legal to dispose of the material in the storm drain. Unless the waste is analyzed and found to be non-hazardous in California, the spent material cannot legally be released to land. Furthermore, the sodium bicarbonate will damage vegetation if it is released to land. The strong advantage of using the dry ice blasting system is that it generates virtually no waste. Combining it with a crushed recycled glass system, which can remove graffiti much faster and more effectively than the soda blasting system, will accomplish the required tasks with much less waste generation.

IV. Alternative Graffiti Removers

Many of the project participants are using graffiti removers that do not comply with the CARB VOC limits. These users were generally unaware of the air regulations and the regulations place the burden of selling VOC compliant graffiti removers on the supplier, not the user. Some of the project participants are also using graffiti removers that contain toxic components. For instance, a few graffiti removers contain methylene chloride which is a carcinogen and several others contain NMP, a reproductive and developmental toxin. Part of IRTA's project involved finding alternative graffiti removers that were low in VOC content and low in toxicity. These alternative graffiti removers would not include either methylene chloride or NMP.

IRTA used a two-pronged approach to find safer alternatives. The first approach involved formulating new graffiti removers that would have low toxicity and low VOC content. IRTA has considerable experience in formulating new products in other solvent alternatives applications. The second approach involved working with the San Francisco DE, one of the project sponsors, to investigate a list of graffiti removers on their website. IRTA evaluated these graffiti removers to determine if they contained toxic components and/or if they complied with the CARB VOC standards based on the MSDSs and conversations with the suppliers. Some of the graffiti removers are no longer offered for sale and a few were eliminated based on the VOC limits. IRTA conducted testing of the remaining graffiti removers to determine their efficacy. These efforts are described below.

4.1.IRTA Formulated Graffiti Removers

There is no one graffiti remover that can accomplish all tasks. Rather, there are several graffiti removers graffiti abatement personnel must use to address specific needs. IRTA recruited the agencies to participate in the project so IRTA could identify these specific problems and attempt to develop graffiti removers to solve them. Not all problems are best solved with a graffiti remover as discussed earlier but all of the participants need to use graffiti removers and they are the best option for many of the problems they encounter on a routine basis. The project had several participants so IRTA could have some assurance that most of the problems that arise for the participants would also arise for other graffiti abatement personnel throughout California and the rest of the country.

In formulating the alternative IRTA graffiti removers, IRTA had three rules. First, the graffiti removers had to meet the VOC limit for nonaerosol graffiti removers established by CARB. This meant the removers must have a VOC content of 30% or less. In general, the graffiti removers IRTA formulated had zero VOC content but in one case, the VOC content was higher, but still well below the 30% limit.

Second, the graffiti removers formulated by IRTA should be low in toxicity. This meant that IRTA would not use ingredients like methylene chloride or NMP. IRTA investigated several potential ingredients for these graffiti removers and a few of them, like some ethylene glycol ethers, also have toxicity problems so these were not used in the formulations.

Third, the graffiti removers had to work well on a range of different graffiti types and, particularly for the task identified by the participant. IRTA made sure that the graffiti removers would effectively remove the types of graffiti commonly encountered in graffiti removal and designed different graffiti removers for specific applications.

4.1.1.General Graffiti Removers

IRTA formulated three different general graffiti removers for removing spray paint and marker from various surfaces. The graffiti removers are extremely aggressive and they work quickly. There may be some painted surfaces on which these removers cannot be used. For instance, as discussed later under films, street signs are screen printed. IRTA's three general graffiti removers would remove the screen printing from the signs and IRTA formulated a different graffiti remover for that application. Two of the graffiti removers may not be suitable for use on certain painted surfaces as they could remove the paint. All three removers might not be suitable for use on some plastic surfaces as the ingredients may craze the plastic. All three of them did not damage hard fiberglass, however, so they could be used on many materials. Commercial graffiti removers often contain a caution to users to test the graffiti removers first in a small section to determine whether they could damage the substrate and/or the paint on a substrate before it is used more extensively and this should be done in the case of IRTA's removers as well.

The three graffiti removers are composed of blends of a soy based material, acetone and benzyl alcohol. The soy based material is Soy Gold 2500 which contains soy methyl esters and a fairly high concentration of surfactant which makes the material water rinseable. An MSDS for this material is shown in Appendix A. IRTA has formulated with this material for numerous applications, including auto aerosol cleaners, general parts cleaning, screen printing and lithographic printing cleanup. This material has very low VOC content and is low in toxicity. Acetone is exempt from VOC regulations and it is lower in toxicity than nearly all other organic solvents. It is used widely in California to comply with the low VOC limits there. IRTA has also formulated many different types of materials using acetone. An MSDS for acetone is shown in Appendix A. Benzyl alcohol has been tested for carcinogenicity and gave negative results. IRTA used the chemical in formulations for stripping cured paint. The material is not defined as a VOC in the CARB Consumer Product Regulation. An MSDS for benzyl alcohol is shown in Appendix A.

IRTA formulated the three chemicals in blends for the general graffiti remover because of their ability to remove certain types of graffiti. IRTA wanted each formulation to be capable of removing both spray paint and marker at a minimum and possibly also stickers. IRTA would have liked to formulate a graffiti remover with only the soy material. This material, however, removes spray paint but does not, by itself, remove markers which are formulated with an alcohol carrier. Neither does it by itself remove stickers. It does remove some adhesive residue and softens stickers. Acetone evaporates very quickly and, although it removes both spray paint and marker, it needs to be combined with a slower evaporating material to retard its evaporation so it can work on the graffiti longer. Benzyl alcohol removes both spray paint and marker and it also removes stickers. It is very aggressive, however, and may also remove cured paint. To take advantage of the benefits and limitations of the three materials, IRTA decided to formulate three general graffiti removers that were combinations of the three solvents.

Several of the agencies participating in the project tested these three graffiti removers and IRTA also tested them in the same set of tests devised by IRTA for the commercial graffiti removers listed by the San Francisco DE; the results of these tests are described below. The participants who tested the graffiti removers found that they worked very well and were aggressive and removed the graffiti quickly.

4.1.2.Sticker Remover

IRTA formulated a specific sticker remover during the project. The MTAi-Trains people have a particular sticker problem with taggers. They put stickers on the seats and the panels of the train walls which are made of fiberglass. A picture of the seats and a picture of a fiberglass panel are shown in Figure 4-1 and 4-2. The sticker remover IRTA formulated contains acetone and benzyl alcohol and the MTA-Trains people tested it and found it to be effective for sticker removal and also as a general graffiti remover.

Figure 4-1. Sticker on back of train seat

Figure 4-2. Sticker on train fiberglass panel

4.1.3.Gentle/Sensitive Surface Graffiti Remover

Street signs, in particular, pose a very hard problem in graffiti abatement. The signs are made of metal and they are fabricated and screen printed by sign shops dedicated to the activity. Nearly all graffiti removers will damage the screen printing on the signs, especially if any scrubbing is required. Although, as discussed later, films can be used on the signs to protect them from damage by graffiti removers,

some agencies, where there is only periodic graffiti abatement needed, want a gentle graffiti remover that can be used to control graffiti on the bare signs.

IRTA formulated a gentle graffiti remover specifically for use on street signs. The challenge was to make a graffiti remover that would not damage the screen printing easily but would remove both spray paint and marker from the signs. The graffiti remover contains Soy Gold 2500 which can remove spray paint and rubbing alcohol which contains a small amount of water and isopropyl alcohol which removes marker. The rubbing alcohol in this graffiti remover can be purchased at any drug store. Simi Valley DPW tested the graffiti remover and found it to be effective. It's worth noting that it is probably impossible to remove stickers from street signs without damaging the screen printing on the sign. As discussed later, the films can help with this problem.

4.1.4.Summary of IRTA Formulated Graffiti Removers

Table 4-1 summarizes the graffiti removers formulated by IRTA. The table indicates the type of graffiti remover and gives the specific composition. In all cases the composition is given in volume percentage.

Table 4-1
Graffiti Removers Formulated by IRTA

Type of Graffiti Remover	Composition (by Volume)
General Graffiti Remover	50% Soy Gold 2500/50% acetone
General Graffiti Remover	50% Soy Gold 2500/50% benzyl alcohol
General Graffiti Remover	50% acetone/50% benzyl alcohol
Sticker Remover	80% acetone/20% benzyl alcohol
Gentle Graffiti Remover	80% Soy Gold 2500/20% rubbing alcohol

4.2.Commercial Graffiti Remover Selection

As part of the project, IRTA analyzed several graffiti removers listed by the San Francisco DE. After an examination of the MSDSs and discussions with the suppliers to see whether the products were still available and whether they met the CARB VOC limits, nine graffiti removers remained. In some cases, it was difficult to assess whether the graffiti removers meet the CARB VOC limits and this is discussed in more detail below. Also in certain instances, it is difficult to determine whether the graffiti removers contain toxic components because the MSDSs are incomplete. This issue too is discussed in more detail below.

4.2.1.CARB Consumer Product Regulations and Toxic Ingredients

CARB regulates graffiti removers in the Consumer Product Regulation. This regulation requires aerosol graffiti removers to have a VOC content of 50% or less and nonaerosol graffiti removers to have a VOC content of 30%. The reason the VOC content limit for the aerosol products is higher is that the propellants selected by suppliers are often VOCs in addition to the ingredients in the graffiti remover itself. CARB prohibits the use of certain toxics, including methylene chloride, perchloroethylene or trichloroethylene, in the consumer product category for graffiti removers.

For purposes of the Consumer Product Regulation, CARB defines VOC differently than the local air districts do. CARB allows the use of LVPs or Low Vapor Pressure materials and does not consider them to be VOCs. The definition of an LVP, in the regulation, is that it 1)has a vapor pressure less than 0.1 mm

Hg at 20 degrees C as determined by ARB Method 310; or 2)is a chemical compound with more than 12 carbon atoms or a chemical mixture comprised solely of compounds with more than 12 carbon atoms as verified by formulation data, and the vapor pressure and boiling point are unknown; or 3)is the weight percent of a chemical mixture that boils above 216 degrees C, as determined by ARB Method 310.

This definition is not as restrictive as the local air district VOC definition. As a consequence, many of the LVPs used to formulate consumer products should actually be classified as VOCs and would be considered VOCs under the local air district definitions. Suppliers of consumer products take advantage of the LVP exclusion and formulate many products with LVPs.

Using the MSDSs for the graffiti removers listed by the San Francisco DE and those used by the project participants, IRTA judged whether the graffiti removers met the CARB VOC limits. In certain cases, IRTA contacted the suppliers as well to try to get more information on the ingredients. The effort has limitations because many of the MSDSs did not list all of the ingredients and IRTA could not use test methods for determining whether a chemical mixture might meet the LVP definition. In some instances, IRTA had to use best judgment as to whether the graffiti remover meets the CARB VOC limits.

Many of the graffiti removers used by the participants do not meet the CARB VOC limits and/or they contain the prohibited toxic component methylene chloride which is a carcinogen and should not be used in graffiti removers. IRTA also evaluated the graffiti removers to see if they contained N-methyl pyrrolidone (NMP) or other obvious toxic components. As discussed earlier, NMP is a reproductive and developmental toxin and IRTA does not consider it to be an acceptable ingredient for graffiti removers. Several of the graffiti removers used by the project participants contain NMP.

Nine of the graffiti removers listed by the San Francisco DE appear to meet the CARB VOC limit and probably do not contain methylene chloride or NMP. It is difficult to tell in certain cases, however, when all of the ingredients in a graffiti remover are not listed. Many suppliers are not willing to reveal the ingredients, claiming that formulating graffiti removers is a highly competitive business. In IRTA's view, if the suppliers are not willing to reveal all of the ingredients to the users, then the users should not purchase the graffiti removers. Agencies should have policies to this effect and should refuse to use graffiti removers if they do not know the full range of the ingredients.

4.2.2.Selection of San Francisco DE Listed Graffiti Removers

The nine graffiti removers that appear to comply with the CARB Regulation include:

- Claire Manufacturing's Green Graffiti Remover
- Motsenbocker's Lift Off #3
- Motsenbocker's Lift Off #4
- Aldran Chemical Inc.'s Graf Off
- Aldran Chemical Inc.'s Hoodlum
- United Laboratories' United 627 Smart Solve Graffiti Wipes
- United Laboratories' United 608 Gelled Graffiti Remover
- Staples Contract & Commercial, inc.'s SE99 Graffiti Remover
- Equipment Trade Service Co. Inc.'s Taginator

An MSDS for each of these graffiti removers is included in Appendix A.

Clair Manufacturing's Green Graffiti Remover contains three components that make up a dibasic ester, which is a solvent, and two types of alcohol ethoxylates that function as surfactants, according to the MSDS.

According to the MSDS, Motsenbocker's Lift Off #3 is designed for removing pen, ink and marker. It is water-based and it contains less than 5% acetone and trade secret ingredients. The main concern about this graffiti remover is that so much of the formulation is listed as trade secret ingredients.

The MSDS for Motsenbocker's Lift Off #4 indicates the graffiti remover is designed for removing spray paint. It is water-based and it contains less than 10% acetone and trade secret ingredients. Again, the main concern for this product is that so much of it is listed as trade secret ingredients.

Aldran Chemical Inc.'s Graffiti Off is a premoistened towel. The MSDS shows that it contains three components of the dibasic ester, ethyl lactate and a linear alcohol ethoxylate which, apparently, serves as a surfactant.

Aldran Chemical Inc.'s Hoodlum is an aerosol graffiti remover. According to the MSDS, it contains 10 to 20% acetone, four solvents at 1 to 10% each and liquid petroleum gas (apparently the propellant) at 25 to 35%.

United Laboratories' United 627 Smart Solve Graffiti Wipes is sold in premoistened form. The MSDS lists alcohol ethoxylate, a surfactant, at 5 to 7% and alkoxylated amine at 1 to 5%. The main concern about this product is that there is very little information on its makeup.

United Laboratories' United 608 Smart Solve Gelled Graffiti Remover has the same listed ingredients in the same percent as the other United Laboratories product. The company is clearly using the same formulation neat and in premoistened wipes. The same concerns about the lack of information about other ingredients that apply to the other product apply here as well.

Staples Contract & Commercial Inc.'s SE 99 Graffiti Remover contains the three components of the dibasic ester, propylene carbonate and two glycol ethers (one of them listed twice). Propylene carbonate is not a VOC and is low in toxicity.

Equipment Trade Service Co. Inc.'s Taginator has two listed ingredients, a glycol ether acetate with no percent composition and potassium hydroxide (at a 45% concentration) with a listed percent composition of less than 10%. The main concern about this product is that there is very little information on its makeup.

4.3.Commercial and IRTA Formulated Graffiti Remover Testing

IRTA devised a testing program to field test the nine graffiti removers listed by the San Francisco DE. The graffiti removers that needed to be field tested and compared are in different forms and have been designed for different purposes. A summary of the characteristics of the nine candidate graffiti removers is provided in Table 4-2 below. IRTA relied on the MSDSs and technical data sheets to develop the information on the substrates and graffiti the removers may be used on. As the table indicates, most of the graffiti removers are in liquid form, but two are towels or wipes, one is an aerosol and one is in the form of a gel. Some of the graffiti removers can remove a variety of graffiti types. In contrast, Lift Off #3 and #4 are designed to remover marker and spray paint respectively. Some are capable of

removing graffiti from porous substrates like brick, stone, sidewalks and concrete. Others are capable of removing graffiti only from hard, non-porous substrates. Some claim to be able to remove graffiti from street signs. For Graff Off and Hoodlum, the supplier had no information on the graffiti that could be removed using the remover. The supplier of two of the graffiti removers, Graf Off and Hoodlum, could not specify the substrates and graffiti the products were designed for.

Table 4-2
Characteristics of Nine San Francisco DE Listed Graffiti Removers

Graffiti Remover	Form	Substrates	Graffiti
Green Graffiti Remover	liquid	brick, stone, concrete plastic, laminate, metal	paint, ink, marker
Lift Off #3	liquid	concrete, brick street signs hard surfaces, fiberglass	marker, ink, dyes
Lift Off #4	liquid	stucco, concrete, brick plastic, metal street signs	spray paint
Graf Off	towel	unknown	unknown
Hoodlum	aerosol	unknown	unknown
United 608	gelled	hard non-porous	paint, ink, marker
United 627	wipes	hard non-porous	paint, ink, marker
SE99 Acetone	liquid	vehicles, buildings sidewalks, bridges street signs	paint, markers, gums
Taginator	liquid	masonry	paint

IRTA talked with the suppliers of the nine graffiti removers and requested that they send samples of their products for testing. Suppliers of two of the graffiti removers indicated they would not send samples of their removers. One of these is Graf Off and the other is SE99 Graffiti Remover. The supplier of the Graf Off indicated that the graffiti remover was not available elsewhere so IRTA could not include the remover in the testing. The SE99 Graffiti Remover is made by Staples and IRTA was able to order a sample from Staples so it was included in the testing. Out of the nine graffiti removers IRTA evaluated, samples of eight of them were obtained for testing.

4.3.1.Field Test Protocol

Based on the MSDSs and technical data sheets available on the graffiti removers and conversations with the suppliers, IRTA structured a set of tests to determine the efficacy of the graffiti removers. As discussed earlier in this section, there is no one graffiti remover that would work for all applications. Removing graffiti from certain types of substrates requires different characteristics. After considering this issue and taking into account the different forms and characteristics of the eight graffiti removers, IRTA decided not to design a rigid protocol that would compare the graffiti removers' efficacy in a strictly defined way. Rather, IRTA wanted to develop a less restrictive protocol that would allow more latitude in exploring and defining the capabilities of each of the graffiti removers. For example, in some

cases, the graffiti removers were reapplied and in others, they were allowed to act on the graffiti for a longer period.

With this in mind, IRTA decided to test some or all of the graffiti removers, as appropriate, on four substrates, including:

- Bare concrete wall to represent a porous masonry substrate
- Fiberglass train panel to represent non-metal hard non-porous substrate
- Back of a street sign to represent a metal hard non-porous substrate
- Front of screen printed street sign to represent a sensitive surface

Table 4-3 shows the four substrates and the graffiti removers that could be tested on each. Only five of the eight graffiti removers could be tested on the concrete wall. Two of the graffiti removers, 608 Smart Solve and 627 Smart Solve, could not be tested on the concrete wall because the instructions indicate they are not suitable for use on porous substrates. Furthermore, the 627 product is a wipe which would not be effective on the wall. Taginator is specifically designed to be used on porous substrates so it was not tested on any of the substrates except the concrete wall. Lift Off #3 was not tested on the concrete wall because the graffiti on the wall was spray paint (see below) which Lift Off #3 cannot remove; the graffiti remover technical data sheet indicates it has been designed to remove marker and ink. Seven of the graffiti removers were tested on the fiberglass panel and the back of the street sign. Six of the graffiti removers were tested on the front of the street sign; again, Lift Off #3 was not tested because the graffiti applied to the sign was spray paint.

Table 4-3
Graffiti Remover Tests on Substrates

	Concrete Wall	Fiberglass Panel	Back of Street Sign	Front of Street Sign
Green Graffiti Remover	TY	T	T	T
Lift Off #3	NT	T	T	NT
Lift Off #4	T	T	T	T
Hoodlum	T	T	T	T
United 608	NT	T	TY	T
United 627	NT	T	T	T
SE99	T	T	T	T
Taginator	T	NT	NT	NT

T indicates tested and NT indicates not tested.

In addition to the commercial graffiti removers, IRTA tested at least one of the IRTA-formulated graffiti removers on each of the four substrates. In the case of the concrete wall, IRTA tested the two IRTA graffiti removers containing benzyl alcohol. In the case of the fiberglass panel and the back of the street sign, IRTA tested the two IRTA graffiti removers containing Soy Gold 2500. For the front of the street sign, IRTA tested the gentle graffiti remover containing Soy Gold 2500 and rubbing alcohol.

IRTA also considered carefully what types of graffiti and how much of it should be applied to the surfaces. In one case, during the testing, IRTA realized that the test protocol was too restrictive and revised it to include a second, less demanding test that would better optimize the capabilities of the commercial graffiti removers. The aim was to present a challenge for the graffiti removers but at the

same time to be aware of the type of graffiti that would likely be encountered in the field on a routine basis.

4.3.1.1.Concrete Testing

For the masonry test, IRTA worked with the Port of San Francisco and used an outside wall near the paint shop at Pier 50. IRTA applied two colors of spray paint, blue and black, to the wall. The black paint was Quick Color Fast Drying All Purpose Spray Enamel and the blue paint was Rust-Oleum Gloss Protective Enamel. The spray paints were applied very heavily over one another to represent the most difficult removal problem that would ever be encountered. In general, as discussed earlier, taggers tend to apply spray paint lightly so they will be able to tag more surfaces with a given amount of paint. As a consequence, this was a more challenging problem than would be usually the case. Figure 4-3 shows the wall with the spray paint applied.

Figure 4-3. Port concrete wall with spray paint applied

The spray paint was allowed to cure overnight and the graffiti removers were tested the next day. Taginator instructions indicated the remover should be applied once and the supplier suggested waiting about 15 minutes for it to act and that it should then be removed with a high pressure water spray system. IRTA applied this graffiti remover only once. Three of the other graffiti removers were to be left on for varying periods of time and the instructions said to use a brush to work them into the graffiti. The Aldran Hoodlum had no instructions. IRTA decided to spray on the four other graffiti removers and the two IRTA-formulated graffiti removers, allow them to work for about five minutes, brush them with a wire brush, reapply them a second time and brush them again. They were all removed with the high pressure water spray system. IRTA tried to optimize the use of the graffiti removers to give them a good chance to work.

The application and brushing of the graffiti removers is shown in Figure 4-4. Figure 4-5 shows the high pressure water spray system and Figure 4-6 shows the system during rinsing. Note that the effluent from the operation is being collected on plastic placed below the wall.

Figure 4-4. Port staff applying graffiti remover to concrete wall

Figure 4-5. Pressure washer rinsing system

Figure 4-6. Concrete wall after rinsing

The wall was allowed to dry for a brief time before inspection. The graffiti removers that worked most effectively were the Lift Off #4, Taginator and the two IRTA-formulated removers. This initial inspection seemed to indicate that virtually all of the spray paint was removed by these four graffiti removers. A picture of the wall at this stage is shown in Figure 4-7. IRTA and the Port staff inspected the concrete wall again about a month after the testing. At that stage, there remained a very faint residue of the spray paint and/or the graffiti removers on the concrete wall for all four of the graffiti removers that were judged to work effectively. The other three graffiti removers left a much more obvious residue of spray paint. The fact that a slight residue remained for the best graffiti removers could be an indication that the spray paint was applied too heavily and that it is unlikely that this would be the case in routine graffiti removal.

Figure 4-7. Concrete wall after graffiti removal

4.3.1.2.Fiberglass Panel Testing

The fiberglass panel is a smooth surface and IRTA masked it off into sections to test all eight of the commercial graffiti removers and the two IRTA-formulated general graffiti removers containing Soy Gold 2500. IRTA applied the same two enamel spray paints fairly heavily to the panel. In addition, IRTA applied a black Sharpie marker and a silver paint marker. IRTA also placed a postal sticker on each of the masked sections. A picture of the masked panel with the graffiti is shown in Figure 4-8.

In general, IRTA applied the liquid graffiti removers to the section, let them act for a few minutes and then scrubbed with a cloth to remove them. If they didn't remove the graffiti, IRTA reapplied the remover a second time and scrubbed them with a cloth. For the graffiti wipe, IRTA scrubbed the graffiti with the wipe and scrubbed a second time, if necessary. In the case of the sticker, to be successful, the graffiti remover should soften it sufficiently so it can be pulled off in one piece. The results are summarized for each of the graffiti removers below.

Figure 4-8. Masked off sections on fiberglass panel

4.3.1.2.1.Green Graffiti Remover

Although the supplier indicated this graffiti remover could be diluted, since IRTA applied the spray paint heavily, IRTA used the graffiti remover at full strength. Both the Sharpie and paint marker came off immediately. Some of the black spray paint came off quickly but the blue paint and the sticker did not come off. IRTA reapplied the graffiti remover. After letting it sit for three minutes, the black paint came completely off and the blue paint started bubbling up but was not completely removed. The sticker did not come off.

4.3.1.2.2.Lift Off #3

This graffiti remover was designed to remove pen and marker and was not designed to remove spray paint. As expected, the remover did not remove the spray paint or the paint marker or the sticker. It did remove the Sharpie marker but left a faint haze.

4.3.1.2.3.Lift Off #4

This graffiti remover was designed to remove spray paint but not marker. Even so, it quickly removed both markers and the black spray paint. The blue paint did not come off right away with scrubbing. IRTA reapplied the graffiti remover, the blue paint bubbled up after about one minute and was easily removed with scrubbing. The remover did not remove the sticker.

4.3.1.2.4.Hoodlum

This graffiti remover is in aerosol form. The graffiti remover removed both markers right away and the blue paint started bubbling up. IRTA reapplied the remover and, after about five minutes, most of the blue paint and some of the black paint was removed with scrubbing. The sticker was not removed.

4.3.1.2.5.United 608

This graffiti remover is in gel form. IRTA applied the graffiti remover and let it act for three minutes. It removed both of the markers easily and a little of the black paint. None of the blue paint and the sticker

could be removed with scrubbing. IRTA reapplied the remover and most of the black paint came off. The blue paint and the sticker were not removed.

4.3.1.2.6.United 627

This graffiti remover is in the form of a premoistened wipe. IRTA scrubbed the section with the wipe for about two minutes. The paint marker and black spray paint came off right away. The Sharpie marker was removed but a stain or haze remained. The blue paint and the sticker did not come off even after scrubbing with another wipe.

4.3.1.2.7.SE99 Green Graffiti Remover

IRTA applied this graffiti remover and let it act for about three minutes. The two markers came off right away. The blue paint bubbled up and most of it came off. Some of the black paint was removed. IRTA reapplied the graffiti remover and let it act. With scrubbing, nearly all of the blue paint and most of the black paint came off. The sticker was loosened but could not be pulled off in one piece.

4.3.1.2.8.IRTA Benzyl Alcohol/Soy Gold 2500 Formulation

IRTA applied the graffiti remover and let it sit for two minutes. The marker and black paint were easily scrubbed off. The blue paint had bubbled up and took a little more scrubbing to remove. The sticker was softened and could be removed in one piece.

4.3.1.2.9.IRTA Acetone/Soy Gold 2500 Formulation

IRTA applied the graffiti remover and the blue paint started bubbling up right away. After about 1.5 minutes, all the graffiti came off. The sticker could be pulled off in one piece.

4.3.1.2.10.Summary of Fiberglass Tests

Table 4-4 summarizes the results of the graffiti remover tests on the fiberglass panel. In this test, IRTA applied the spray paint and marker heavily and many of the graffiti removers took a significant amount of time to work or did not work well on some of the graffiti. A yes in the table indicates the graffiti remover effectively removed the graffiti; a no indicates, it did not. As described below, IRTA conducted a second set of tests where the spray paint was applied more sparingly to the fiberglass panel and no other graffiti was applied. In that case, only the black spray paint was applied.

4.3.1.3.Second Set of Fiberglass Panel Tests

Because some of the commercial graffiti removers had a hard time removing the spray paint which IRTA heavily applied, IRTA decided to do a second test with the spray paint lightly applied on the fiberglass. IRTA also applied only the black spray paint which is more likely to be the kind taggers would use. A picture of the fiberglass panel with this paint applied is shown in Figure 4-9. In this case, IRTA did not let the removers work but began scrubbing them off right away after application. All of the graffiti removers except Lift Off #3 worked well and removed all of the paint with scrubbing. Again, Lift Off #3 was designed to remove marker, so it is not surprising it did not remove the spray paint.

Table 4-4 Graffiti Remover Comparison on Fiberglass Panel with Heavy Graffiti			
Graffiti Remover	**Spray Paint Removed**	**Marker Removed**	**Sticker Removed**
Green Graffiti Remover	black not blue	Yes	No
Lift Off #3	No	Sharpie, not paint	No
Lift Off #4	Yes	Yes	No
Hoodlum	Some	Yes	No
United 608	some black, not blue	Yes	No
United 627	black, not blue	paint, not Sharpie	No
SE99	most of black, some blue	Yes	No
IRTA SG2500/BA	Yes	Yes	Yes
IRTA SG2500/Acetone	Yes	Yes	Yes

BA is benzyl alcohol

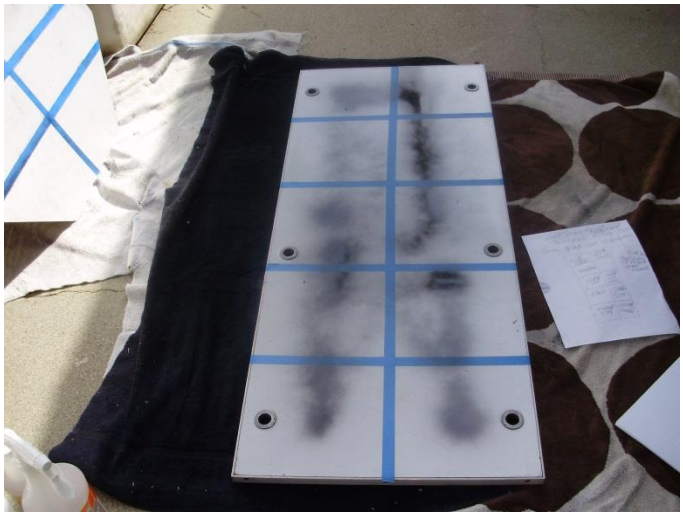

Figure 4-9. Fiberglass panel with light spray paint applied

4.3.1.4.Back of Street Sign—Metal Substrate

To test the graffiti removers on the metal back of a street sign, IRTA applied both colors of the spray paint lightly and the Sharpie and paint marker. A picture of the masked off street sign with the graffiti on it is shown in Figure 4-10. Many street signs are made of aluminum and this test was meant to represent the capabilities of the graffiti removers for removing graffiti from metal substrates.

IRTA applied the Lift Off #3 and left it on for three minutes. It removed the Sharpie marker and the black spray paint but not the blue spray paint or the paint marker. Again, this graffiti remover is designed to remove marker but not paint. IRTA applied Lift Off #4, SE99 and United 608 and let them sit for two minutes. With scrubbing, all the graffiti was removed. IRTA applied the Green Graffiti Remover and let it sit for two minutes. With scrubbing, the black paint and markers were removed. IRTA reapplied the graffiti remover and, with scrubbing, removed the blue paint. IRTA applied Hoodlum and let it sit for two minutes. All but the black spray paint was removed with scrubbing. IRTA reapplied the remover and was able to remove the black spray paint with scrubbing. IRTA scrubbed with the United 627 wipe for about 1.5 minutes and all of the graffiti came off but the black spray paint was the hardest

to remove. IRTA applied the IRTA-formulated removers and did not let them sit. With scrubbing, all of the graffiti was removed.

Figure 4-10. Masked off metal sign with graffiti applied

The results of the testing are summarized in Table 4-5. A yes in the table indicates the graffiti remover effectively removed the specified graffiti; a no indicates it did not. All of the graffiti removers except Lift Off #3 were able to remove the two types of paint and two types of markers. Lift Off #3, again, was not designed to remove spray paint but, even so, it did remove the black spray paint. Most of the graffiti removers required scrubbing. This test demonstrates that graffiti removal is easier from some substrates than others. IRTA did observe early on during the project, that graffiti removal from metal substrates is easier than removal from other types of substrates. In this test, the graffiti was applied lightly and many graffiti removers can remove lightly applied graffiti with scrubbing.

Table 4-5
Graffiti Remover Comparison on Back of Metal Street Sign With Light Graffiti

Graffiti Remover	Black Spray Paint	Blue Spray Paint	Paint Marker	Sharpie Marker
Green Graffiti Remover	Yes	Yes	Yes	Yes
Lift Off #3	Yes	No	No	Yes
Lift Off #4	Yes	Yes	Yes	Yes
Hoodlum	Yes	Yes	Yes	Yes
United 608	Yes	Yes	Yes	Yes
United 627	Yes	Yes	Yes	Yes
SE99	Yes	Yes	Yes	Yes
IRTA SG2500/BA	Yes	Yes	Yes	Yes
IRTA SG2500/Acetone	Yes	Yes	Yes	Yes

BA is benzyl alcohol

4.3.1.5.Front of Street Sign

In this case, IRTA used only the black spray paint and applied it lightly. For street signs, it is important to use a graffiti remover that is gentle enough that it does not remove the screen printing on the sign.

IRTA applied all the graffiti removers and removed them right away so they did not soak in and remove the screen printing. Figure 4-11 shows the front of the street sign with the light graffiti.

Figure 4-11. Street sign with light graffiti

IRTA did not test Lift Off #3 in this instance since it is designed to remove marker and not spray paint. Four of the graffiti removers, Lift Off #4, United 608, United 627 and Green Graffiti Remover, removed the graffiti and did not damage the screen printing on the sign. Two of the graffiti removers, SE99 Green Graffiti Remover and Hoodlum, removed the graffiti but also removed the screen printing. IRTA also tested IRTA's gentle graffiti remover (a blend of Soy Gold 2500 and rubbing alcohol) and it removed the graffiti and did not damage the screen printing. In this case, the graffiti remover must be aggressive enough to remove the spray paint quickly so scrubbing is not necessary but it also must not damage the screen printing. Table 4-6 summarizes the results of the testing. Again, a yes indicates the graffiti remover effectively removed the graffiti and a no indicates it did not.

Table 4-6
Graffiti Remover Comparison on Front of Street Sign with Black Spray Paint

Graffiti Remover	Removed Spray Paint	Removed Screen Printing
Green Graffiti Remover	Yes	No
Lift Off #4	Yes	No
Hoodlum	Yes	Yes
United 608	Yes	No
United 627	Yes	No
SE99	Yes	Yes
IRTA Soy Gold 2500/ Rubbing Alcohol	Yes	No

4.3.1.6.Summary of Graffiti Remover Testing

The testing indicates that the graffiti removers vary in their ability to remove certain kinds of graffiti and they also vary according to the substrate material that is the graffiti surface. Table 4-7 summarizes the results of the testing. As before, a yes signifies the graffiti remover was effective and a no indicates it was not.

In general, the commercial graffiti removers were not very effective in removing heavy spray paint and marker from the fiberglass surface. None of the commercial graffiti removers was effective in removing the postal stickers. The commercial graffiti removers performed better on the fiberglass substrate when faced with removing light spray paint; all of them except Lift Off #3, designed for marker remover, removed the spray paint. IRTA's graffiti removers removed the heavy graffiti more easily than the commercial graffiti removers and were able to also remove the postal sticker.

The commercial graffiti removers and IRTA's graffiti removers performed better in removing graffiti from the metal substrate. This demonstrates that the material of construction of the substrate matters significantly for graffiti removal. Some of the commercial graffiti removers and one of IRTA's graffiti removers were effective in removing spray paint from a street sign without damaging the screen printing on the sign.

Table 4-7
Graffiti Remover Comparison for Graffiti on Various Substrates

Graffiti Remover	Concrete Heavy Spray Paint	Fiberglass Heavy Spray Paint Marker, Stickers	Fiberglass Light Spray Paint	Metal Light Spray Paint Marker	Street Sign Light Spray Paint
Green Graffiti Remover	No	Some paint, marker	Some	Yes	Yes
Lift Off #3	NT	Sharpie marker	No	Some paint, Sharpie	NT
Lift Off #4	Yes	Paint and marker	Yes	Yes	Yes
Hoodlum	No	Some paint, marker	Yes	Yes	Damage
United 608	No	Some paint, marker	Yes	Yes	Yes
United 627		Some paint, marker	Yes	Yes	Yes
SE99	No	some paint, marker	Yes	Yes	Damage
Taginator	Yes	NT	NT	NT	NT
IRTA SG2500/BAA	Yes	Yes	Yes	Yes	NT
IRTA BA/Acetone	Yes	NT	NT	NT	NT
IRTA SG2500/Acetone	NT	Yes	Yes	Yes	NT
IRTA SG2500 Rubbing Alcohol	NT	NT	NT	NT	Yes

NT indicates not tested; BA refers to benzyl alcohol; SG is Soy Gold.

4.4.Cost Analysis of Commercial and IRTA Formulated Graffiti Removers

IRTA tested only certain graffiti removers that were on a list provided by one of the project sponsors, the San Francisco DE. The commercial graffiti removers IRTA tested were generally designed by the companies who make them to function as general graffiti removers or accomplish a specific task. For

instance, none of the graffiti removers was designed to remove stickers and they were not able to remove the stickers during the testing. In some cases, these same companies may have graffiti removers deliberately designed to remove stickers that would be better able to accomplish that task. For example, Motsenbackers has a sticker remover they market specifically for that purpose.

The five graffiti removers IRTA formulated generally performed well in the testing. This is because IRTA designed these graffiti removers to remove several types of graffiti they would encounter. IRTA generally used the Soy Gold 2500 as a good spray paint remover. IRTA used benzyl alcohol, acetone or rubbing alcohol to remove the Sharpie marker. For the more aggressive removal applications, like removing spray paint from concrete, IRTA relied on the benzyl alcohol formulations since benzyl alcohol can remove cured coatings. For more delicate substrates, like bare street signs, IRTA used rubbing alcohol instead so the screen printing would not be damaged. Both acetone and benzyl alcohol, and also soy in blends with these two materials, are effective in sticker removal so IRTA formulated these removers accordingly.

In order to conduct a cost analysis and comparison, IRTA would need much more information from the testing. This is the removal rate in terms of square feet of graffiti removed per volume of graffiti remover used. This information is not available. It depends on the type of graffiti being removed and how heavy the graffiti is on the surface. IRTA did collect general cost information per volume on each of the graffiti removers and also estimated what the cost of the graffiti removers IRTA formulated might be, based on the raw materials cost and a typical markup. This information is presented below and may assist users in selecting a specific graffiti remover for their task.

4.4.1.Cost Information on Commercial Graffiti Removers

Some of the graffiti removers analyzed by IRTA are sold on line to consumers and businesses. These include Motsenbacker Lift Off #3, Motsenbacker Lift Off #4 and SE99. Hoodlum is sold by the supplier. Green Graffiti Remover, Taginator, and United 608 and 627 are sold by distributors who represent the manufacturer. In some cases, the liquid graffiti removers are sold in 22 ounce bottles with a spray trigger; in other cases, they are sold in 32 ounce bottles. Often, six bottles are packaged in a six pack at a lower price. The smaller the packaging is, the higher the price. Hoodlum, because it is an aerosol, carries a higher price per volume because aerosol packaging is expensive, but convenient.

Table 4-8 presents price information on the commercial graffiti removers tested during the project. The table shows the graffiti remover, the package size and the price. A case is six bottles; a case is 12 cans for Hoodlum, the aerosol product and 12 containers for United 608.

Table 4-8
Price Information on Commercial Graffiti Removers Tested

Graffiti Remover	Package Size	Price
Lift Off #3	22 ounce bottle	$14.99 to $17.55
	32 ounce bottle case	$83.01
Lift Off #4	32 ounce bottle case	$65.96 to $85.59
Hoodlum	16 ounce can case	$80
United 608	16 ounce can case	$30.66
United 627	70 wipes case	$56.40
SE99	32 ounce bottle	$22.99
Taginator	quart bottle (32 ounce)	$18.31

The prices in Table 4-8 demonstrate that a 32 ounce container might range in price from about $10 to $25, depending on the quantity purchased for several of the graffiti removers. Most of the commercial products fall into this price range which is very large. The United 608, a gel product, is higher cost. United 627, which comes in wipes, and the Hoodlum aerosol are also higher cost products.

4.4.2.Cost Estimates for IRTA Formulated Graffiti Removers

It is difficult to estimate a cost for the graffiti removers IRTA formulated for testing during this project. IRTA discussed the pricing practices with a few different graffiti remover suppliers. Two suppliers indicated that pricing was determined by suppliers based on what the market would bear. Another supplier indicated that a reasonable price was about four to six times the raw material cost but that many suppliers charged seven to ten times the raw materials price for their products.

IRTA contacted suppliers of some of the raw materials used in IRTA's graffiti removers. These prices are based on drum quantity purchases of acetone, benzyl alcohol and Soy Gold 2500. IRTA made no attempt to minimize these raw materials cost which would commonly be done by any supplier. The chemicals could certainly be purchased at much lower price if competitive pricing were obtained. The estimates made here are therefore upper bounds to the raw materials prices for these materials.

IRTA obtained a price of for a one drum purchase of Soy Gold 2500 of $2.12 per pound for a 55 gallon or 400 pound drum. The drum price is $848 or a price of $15.42 per gallon or $3.85 per quart or 32 ounces. IRTA obtained a price of $770 for a 55 gallon drum of acetone. This translates into a price of $14 per gallon or $3.50 per quart. IRTA obtained a price of $2.23 per pound for a 353 pound or 55 gallon drum of benzyl alcohol. This translates into a price of $787 for the drum. This amounts to $14.31 per gallon or $3.58 per quart.

Using these high estimates, the blend of 50% Soy Gold 2500/50% benzyl alcohol would have a materials cost of $3.72 per quart. Using the rule of thumb that the graffiti remover would be priced four to six times this cost, the graffiti remover would be sold for $14.88 to $22.32. The blend of 50% acetone/50% benzyl alcohol would be priced at $14.16 to $21.24 per quart, using the same assumptions. The blend of 50% Soy Gold 2500/50% acetone would be priced at $14.72 to $22.08. The three prices are well within the price range of the commercial graffiti removers. Again, these prices are probably on the high end because no attempt was made to find the lowest prices for the raw materials. The results show that suppliers could formulate and sell IRTA's graffiti removers and price them competitively.

V. Methods of Protecting Substrates

Signage is everywhere and signs of all kinds, including advertising signs, large and small billboards and street and highway signs, present a good target for taggers. Taggers use spray paint, marker and stickers of various types to deface the signs. Graffiti control is a significant problem for cities, counties, state agencies and private companies who own and manage the signs. Many of the participating organizations indicate there is a problem with street signs.

Taggers also often deface glass and plexiglass. There are windows in vehicles, stores and buildings and plexiglass often covers signage and these are good targets for taggers since they are clear and often large expanses. In some cases, taggers apply traditional types of graffiti like spray paint, markers and stickers and in other cases, taggers etch the glass or plexiglass. Some of the project participants indicate that defacement of glass and plexiglass is a problem.

Masonry products like concrete, stucco and granite are construction materials used on sidewalks, buildings and walls in thousands of different locations in California. Taggers deface all of these types of surfaces with graffiti. Spray paint is generally the choice of taggers for these substrates because they are porous and marker ink or stickers do not adhere to them readily. Some of the project participants have problems managing graffiti on masonry.

There are many other substrates, including fiberglass, metal and plastic, which are targeted by taggers. All of the project participants must deal with defacement of a wide range of substrates on a regular basis. This section focuses on methods that can be used to minimize or eliminate the effects of tagging on surfaces of various kinds.

5.1.Films

There are a variety of different types of films that have been designed to protect signage and glass from taggers. In general, the films are appropriate for smooth surfaces that are uniform and not porous. The films or laminates, which are generally clear, fall into two categories. The first category is sacrificial films and the second category is non-sacrificial films. Sacrificial films are designed for one time use; they are applied to the substrate and, when they are tagged with graffiti, they are pulled off and replaced with a new film. Non-sacrificial films are designed to be used over a much longer timeframe. When they are tagged, graffiti removers or other methods can be used to remove the graffiti. IRTA's work with these films is discussed below.

5.1.1.Sacrificial Films

IRTA did not investigate sacrificial films extensively. In principle, these films can be used for a variety of applications including all types of signage but most of the products appear to be largely designed for use on glass or plexiglass. The films have a pressure sensitive adhesive backing that sticks to the substrate and it might not stick adequately to all substrates. Probably the most useful application for these films is for glass or plexiglass.

5.1.1.1.Sacrificial Film Testing

Taggers apply graffiti like spray paint, marker and stickers to glass and plexiglass . Taggers also etch the glass with hydrogen fluoride solutions and diamond tipped tools they can readily find at graphics supply stores at very low prices.

One of the project participants, MTA-Trains, routinely uses these films on the train windows. When the film is tagged, it is torn down and replaced with new clear film. The films are a convenient and fast way of removing the graffiti quickly but this method is also likely to be expensive. Another option is to use a graffiti remover directly on the glass and this can work well in many instances. In the case of plexiglass, many commercially available graffiti removers could etch the plexiglass so films may be a better option in this instance.

IRTA tested two different sacrificial films in a limited way. In one case, IRTA applied the film to a piece of glass, put graffiti on the film and pulled the film off. In the other case, IRTA applied a different film to a piece of plexiglass, put graffiti on the film and pulled the film off. It is important to note that different types of film must be used for glass and plexiglass. If the glass film is applied to plexiglass, it will bubble up and not stick adequately to the substrate. The film seemed to perform its function well on both substrates. Sacrificial films could be used to protect street signs, although IRTA did not test them for this purpose. As discussed below, non-sacrificial films are more appropriate and a less expensive option for that application.

Sacrificial films may also be useful on glass and plexiglass for minimizing the effects of etching. Taggers do not know the glass or plexiglass is covered with a film because it is transparent and very thin. When taggers etch, they may only etch the surface, so the film may take the brunt of the etching. If the surface of the glass or plexiglass is not damaged, the film can be pulled off and replaced. As discussed later in the next section, there is another option for dealing with etched glass but it is expensive.

5.1.2.Non-Sacrificial Films

IRTA investigated non-sacrificial films much more extensively than sacrificial films. Most of the project participants, including Muni-Trains, MTA-Structures, San Francisco DPW, the Port of San Francisco and Simi Valley DPW, were interested in exploring this option for road signs. Street sign graffiti is a major problem for most of the participants and for every city and county organization in the state.

5.1.2.1.Non-Sacrificial Films for Road Signs

Road signs rely on colors, words, shapes and symbols to communicate a message to drivers. For example, speed limit signs are generally rectangular and use a white background whereas stop signs have an octagonal shape and red background easily visible to a driver. Virtually all traffic signs use a retroreflective sheeting designed to reflect light from headlights back to the driver so the signs are visible at night. The federally approved Manual on Uniform Traffic Control devices mandates that all signs must be either illuminated or reflectorized.

5.1.2.1.1.Traffic Sign Manufacture

There are many companies in California that manufacture traffic signs for use by city, county or private entities responsible for maintaining them. Virtually all of these agencies contract with the traffic sign companies to make the signs for them; only rarely, if ever, do the agencies make their own signs.

Traffic signs are made of three components. The first component is the blank which is made of plywood, aluminum or steel. By far, the most common material used to make traffic signs is aluminum. The second component is background sheeting which consists of tiny glass beads or microprisms embedded in a flexible plastic surface. The sheeting can be died with a pigment; for stop signs the sheeting is red, for example. The third component is the screen printing which is applied to the background sheeting.

Different levels of reflectively are used on different types of signs. Type I signs are the least reflective and have the narrowest viewing angle and they include parking signs. Type IV signs are about seven times more reflective than Type I signs and they reflect light at a very wide angle. The sheeting used on these signs is microprismatic diamond grade sheeting which has a pattern of small squares superimposed on a hexagonal lattice. A picture of a stop sign is shown in Figure 5-1 and a picture of a no parking sign is shown in Figure 5-2.

Figure 5-1. Stop sign with graffiti

Figure 5-2. No parking sign with graffiti

5.1.2.1.2.Traffic Sign Graffiti Removal

Traffic signs are actually quite delicate because the screen printing on the signs is not very resistant to the solvents used in graffiti removers. When agencies use graffiti removers on the bare signs, the screen printing is often removed. Once in a while, if the graffiti is light, it can be removed with water and a magic eraser. Otherwise, if the graffiti is heavier or, if postal stickers are on the sign, a graffiti remover will have to be used. Many graffiti removers end up removing the screen printing and the sign is too compromised for further use. In that event, the sign would have to be replaced. There are some graffiti removers that are gentle and they might be suitable for use on sensitive surfaces like street signs (see graffiti removers in Section IV). If the graffiti is heavier or if postal stickers are on the signs, even these graffiti removers, if left on for a period and/or if scrubbing is necessary, will end up taking some of the screen printing off the sign.

It is expensive to replace a sign every time a tagger puts a sticker or heavy graffiti on it. A better option, one that is often recommended by the commercial sign shops, is to use a film on the surface of the street sign. These films are often referred to as overlaminates. They are transparent overlays that cover the whole surface of the street sign and they protect the screen printed sign from the graffiti remover.

One sign shop representative estimates that 90 percent of the cities and counties in California use sheeting and images made by 3M. The company also offers a protective overlay film which is designed as a high performance protective transparent material for the signs. The film is a durable, solvent resistant, transparent fluoropolymer film coated with a transparent pressure sensitive adhesive. It provides a barrier to permanent staining from graffiti like spray paint and marker. The film can be applied to the finished sign at the sign shop with a mechanical or hand squeeze roller. Many sign shops recommend the use of the film for most signs that have high reflectivity including speed limit signs, stop signs and school signs.

Other suppliers provide protective transparent film as well. One supplier, for instance, has a polyester based film that can be used on certain street signs. The primary market for this film, however, is signage other than street signs. 3M will warranty the signs for a minimal reflectivity decline only when matched component systems are used. In other words, if the sign uses the 3M sheeting as the base, the film

overlay must be the 3M brand or the company may not stand behind the warranty. Sign shops are anxious to avoid warranty problems so they have policies that require the use of matched components. Since the vast majority of the signs made in California use the 3M sheeting, the film most commonly used on street signs is also made by 3M. In certain cases, where users have their own dedicated sign shops, they can use films provided by other companies if they choose. In many instances, signs in heavy sunlight do not maintain their reflectivity for 10 years anyway.

5.1.2.1.3.Traffic Sign Film Tests

IRTA conducted a great deal of testing of the overlaminate films on street signs. IRTA obtained a number of discarded signs from Simi Valley for the testing and tested two types of films, the 3M fluoropolymer film and the polyester based film marketed by Vandal Guard.

Figure 5-3 shows the 3M film on a stop sign. IRTA tested this film extensively during the project. IRTA applied different types of graffiti to the film. The same blue and black spray paint used in the graffiti remover tests for various substrates in Section IV was used. IRTA applied the spray paint heavily. IRTA also applied the two types of marker, Sharpie marker and paint marker, to the film. Finally, IRTA applied a postal sticker to the film.

Figure 5-3. Stop sign with 3M film

IRTA experimented with different ways of removing the graffiti from the 3M film. Fluoropolymer materials are designed to be non-stick. Pots and pans are often coated with fluoropolymers to make them non-stick during cooking. The fluoropolymer street sign film does not appear to absorb the graffiti and the graffiti largely stays on the surface of the film. As a result, it can be removed quite easily. Postal stickers can be lifted directly off the film. Some of the spray paint and both types of markers can be lifted from the surface of the film with painters tape and clear packaging tape. 3M also makes a tape that is specifically designated to lift graffiti from the film. In IRTA's experience, clear packaging tape is the most effective in lifting the graffiti. In cases where the graffiti is applied very lightly, the tape may effectively remove virtually all of the graffiti. In cases where the graffiti is heavy, there generally remains a residue of spray paint and/or marker after the packaging tape has lifted much of it from the surface of the film.

A graffiti remover can be used to remove the remaining graffiti from the film. Although the fluoropolymer is fairly resistant to many types of solvents, aggressive solvents can end up seeping under the edges of the film. IRTA found that the graffiti could be removed with nonaggressive solvents. As discussed under graffiti removers earlier, IRTA formulated a gentle graffiti remover for removing graffiti from bare street signs and it also functioned well in removing graffiti from the 3M polymer film. A soft cloth should be used with the graffiti remover since abrasion could damage the film.

IRTA also conducted testing with another polyester based film made by Vandal Guard. This film is most commonly used for protecting signage of various types but is generally not used for street signs because of the warranty issue. In some cases, however, if agencies have their own sign shops and are not concerned about maintaining the warranty, they can use this film or other types of films.

A picture of a stop sign with the 3M fluoropolymer film and the Vandal Guard film is shown in Figure 5-4. The Vandal Guard film behaves very differently than the 3M film. In the case of the Vandal Guard film, the graffiti does not stay on the surface of the film but, rather, seems to penetrate the film matrix. For example, stickers cannot simply be pulled off and tape does not pull up any of the graffiti from the surface of the film. Graffiti removers must be used to remove all of the graffiti and soften the sticker so it can be removed. IRTA's gentle graffiti remover was not sufficiently aggressive to remove the graffiti from this film. IRTA's other more aggressive graffiti removers discussed earlier that are based on benzyl alcohol, acetone and soy were able to remove the graffiti effectively and soften the sticker so it could be removed. Although the graffiti is more difficult to remove on this film, the film is effective in protecting the sign and, as discussed below, it is much less costly to use than the 3M film.

5.1.2.1.4.Cost Analysis for Traffic Sign Films

According to one sign manufacturer, the cost of a typical stop sign to an agency is about $35. The cost of adding the 3M film to a typical stop sign is $15 to $16 or a total cost of about $50 or $51. Some areas where street signs are used are high graffiti areas and some are not. In a high graffiti area, a bare sign may have to be replaced relatively quickly and in a low graffiti area, the sign may last much longer before it needs to be replaced.

The cost of purchasing a sign with the film is 46 percent higher than the cost of purchasing a sign without the film assuming the $51 cost for the sign with film. This indicates that, if a sign with film lasts 46 percent longer than a sign without film, then it is cost effective to use the film. For example, if a sign without film lasts one year, then it is cost effective to use the film if the sign lasts about 18 months. This analysis does not take into account the labor cost of replacing the sign more often. If this cost were considered, the film option would be even more attractive. Because signs are so easily destroyed by graffiti removers, it is very likely that the film is a cost effective option because it would extend the life of the sign substantially. It is easy to understand why sign shops recommend the film to agencies.

In some cases, as discussed earlier, agencies may have their own dedicated sign shops and may not be concerned about the warranty. In such cases, these agencies could use the Vandal Guard film rather than the 3M film. According to a 3M representative, the cost of purchasing the 3M film is about $1.60 per square foot. A Vandal Guard representative indicates that the cost of purchasing a roll of their film that is 54 inches wide and 100 feet long is $260. This translates into $0.58 per square foot. This is significantly less costly than the 3M film so using alternative film is certainly an attractive option for those users that do not value the warranty.

5.1.2.2.Non-Sacrificial Films for Other Substrates

The 3M film is designed specifically for use over the 3M background sheeting. It may stick to some other substrates, like glass and plexiglass, if the surface is prepared properly. As is the case for sacrificial film, these permanent films may fool taggers who etch glass and the etch may only penetrate the film. The permanent film would be a much more expensive option than the sacrificial film, however. In addition, the sacrificial film would be a better option because it could be pulled off the glass or plexiglass and replaced with a new film when the old film was damaged.

5.2.Graffiti Resistant Coatings

Graffiti resistant coatings are often referred to as anti-graffiti coatings. They are designed to cover substrates of all kinds and they generally come in clear or pigmented options. The theory is that taggers will tag the coating and many of them advertise that the graffiti can be removed easily. In practice, as discussed below, the graffiti is actually difficult to remove. Even so, these coatings are useful for certain applications. One of the project participants, the contractor who maintains the Bill Graham Concert Hall, currently uses a graffiti resistant coating on the granite building surface. He was experiencing a problem when he tried to remove the graffiti. The coating surface would shadow and IRTA found that this is a common problem with graffiti resistant coatings. IRTA did not know if the problem was a consequence of the coating, the graffiti remover or both. As a result IRTA decided to investigate graffiti resistant coatings as part of the project for this and other applications.

5.2.1.Local Air District Regulations on Coatings

The VOC content of coatings is regulated by the local air districts in California. IRTA reviewed the regulations in the Bay Area and South Coast Basin which together cover perhaps three-fourths of the state. The other air districts in the state often follow the lead of the two larger districts so the BAAQMD and the SCAQMD regulations are representative of the state as a whole. Each of the regulations is discussed below.

5.2.1.1.BAAQMD Coating Regulation

Graffiti resistant coatings are regulated in BAAQMD Regulation 8, Rule 3 “Architectural Coatings.” In this regulation, graffiti resistant coatings are classified as Industrial Maintenance Coatings because they undergo …”frequent scrubbing with industrial solvents, cleansers….” when the graffiti is removed from them. The VOC content for these coatings is 250 grams per liter. In certain cases, if the supplier has written approval from the BAAQMD, the coatings are permitted to have a VOC content of 340 grams per liter. One of the coatings tested by IRTA contains a carrier solvent called tert-butyl acetate (TBAC) and this chemical is considered to be a VOC for purposes of the BAAQMD regulations.

5.2.1.2.SCAQMD Coating Regulation

Graffiti resistant coatings are regulated in SCAQMD Rule 1113 “Architectural Coatings.” In this regulation, the coatings are called Non-Sacrificial Anti-Graffiti Coatings and they are regulated as Industrial Maintenance Coatings. The current VOC limit for these coatings is 100 grams per liter. In contrast to the BAAQMD, SCAQMD has deemed TBAC exempt from VOC regulations when it is used in Industrial Maintenance Coatings. The exemption is limited to this rule but it does apply to graffiti resistant coatings.

5.2.2.Coatings Tested by IRTA

IRTA tested six different types of coatings as part of the project. One of the coatings that was tested was the coating used by the Bill Graham Concert Hall contractor which served as the baseline coating. IRTA investigated a variety of different coatings and types of coatings and talked with a number of suppliers to determine which types would be best to test. In addition, IRTA wanted to ensure that the coatings that were tested meet the VOC limits established by the air districts. The coatings IRTA tested are described below and MSDSs for the coatings are provided in Appendix B.

5.2.2.1.Monopole Inc. Permashield Premium

The coating is a clear two component water-based polyurethane coating with a reported VOC content of zero. It has been formulated for use on a variety of unpainted or painted substrates including concrete, other masonry products and prepared metal. It is provided as a clear or pigmented coating.

5.2.2.2.Surtec, Inc. Graffiti Barrier VOC

This coating is a low gloss, high performance two component polyurethane/acrylic clear coating intended for graffiti protection of concrete and other masonry substrates. The coating has a VOC content of 44 grams per liter. The acrylic resin component is water-based. This is the coating used currently on the Bill Graham Concert Hall.

5.2.2.3.BDC's 4320 Anti-Graffiti Coating

This coating is a high gloss blend of polyurethanes and nanotechnology. It relies on a carrier solvent that is exempt from VOC regulation and the reported VOC content is less than 5 grams per liter. It is intended for use on a range of surfaces including porous substrates like brick and concrete as well as painted stucco and metals of various kinds.

5.2.2.4.Professional Products' Anti-Graffitiant PWS-15 Super and PWS-8 Extra

This coating is designed specifically for use on porous masonry substrates like block, brick, concrete and stone. It is based on silicone rubber and the carrier solvent is exempt from VOC regulation. The coating reportedly complies with the SCAQMD regulations.

5.2.2.5.Coval Molecular Coatings' Anti Graffiti Coat and Metal Coat

Coval has several different versions of a coating for various substrates. The coatings are suitable for use on concrete, metal, wood, painted surfaces and some plastic substrates. The coating is available in gloss and satin finishes. It is a one component nanocoating that uses either methyl acetate or TBAC as the carrier solvent. The reported VOC content is less than 100 grams per liter. The methyl acetate version of the coating must be used in the Bay Area since TBAC is not exempt there. IRTA tested two of the Coval coatings; one of them, called Anti-Graffiti Coat, was tested on masonry and another, called Metal Coat, was tested on street signs.

5.2.3.Graffiti Resistant Coating Tests

IRTA tested the first four coatings listed above together and tested the Coval coatings at a later date. A major challenge for many agencies is graffiti removal from masonry surfaces and IRTA wanted to test the coatings for protecting these surfaces. In addition, the Bill Graham Concert Hall already uses the Surtec graffiti resistant coating and the manager was experiencing problems with graying when he used a graffiti remover on the coating. IRTA wanted to investigate the coatings for masonry surfaces in general and to solve the specific problem the manager was having. IRTA also tested the coatings, to a more limited extent, on other substrates. The results are discussed below.

5.2.3.1.Graffiti Resistant Coating Tests on Masonry Surfaces

IRTA conducted testing at Pier 50 at the Port of San Francisco near the paint shop. IRTA tested the first four coatings on three substrates, including a concrete wall, pieces of granite and a painted stucco wall. One of the coatings, the PWS-15 Super/PWS-8 Extra, was not applied to the stucco wall because it is not appropriate for painted substrates. IRTA discussed the application methods necessary for each of the coatings with the coating suppliers. The instructions varied, depending on the coating. Some of the coatings require a sealer and two sealer coats were applied for the Surtec and Monopole coatings on all three substrates. Pictures of the coatings applied to the concrete wall, the painted stucco wall and the granite pieces are shown in Figures 5-4 through 5-6.

Figure 5-4. Graffiti resistant coatings on concrete wall

In Figure 5-4, the Monopole and Surtec coatings are in the bottom two quadrants. The left hand upper quadrant is the PSW-15/PWS-8 coating and the upper right hand quadrant is the BDC coating. Note that the BDC coating discolored the concrete significantly and, for that reason, this coating would not be acceptable for use on concrete. It was carried through the testing, however. The same coating did not seem to discolor or stain the painted stucco or the granite. The PSW-15/PWS-8 coating discolored the surface of the concrete only slightly and it could be acceptable for use on this substrate. Discoloring of masonry surfaces can be a problem because often, the graffiti resistant coating is used only on the bottom of a masonry surface which is the area accessible by taggers. With a coating that discolors, there is a definitive difference between the color of the bottom and top of the building and this is considered unsightly by many building managers.

Figure 5-5. Graffiti resistant coatings on painted stucco

Figure 5-6. Graffiti resistant coatings on granite pieces

The coatings had a range of different cure times and one of them required a month to fully cure. IRTA waited somewhat more than a month to conduct the testing. At that stage, IRTA applied heavy concentrations of spray paint to the coated sections on the three substrates. Both black and blue spray paint were used and layered on top of each other. IRTA also applied black Sharpie marker and silver paint marker to the substrates even though it is unlikely Taggers would use markers on porous substrates. The substrates with the graffiti are shown in Figures 5-7 through 5-9. IRTA allowed the graffiti to cure overnight and conducted the tests the next day.

Part of the purpose of the tests on the granite was to determine why the granite with the Surtec coating was graying when graffiti remover was applied at the Bill Graham Concert Hall. The graffiti remover used by the manager of the Bill Graham Concert Hall was not an acceptable graffiti remover because it contained several toxic components. IRTA decided to use two other graffiti removers for the testing. The first was a graffiti remover made by Surtec, called L.O.S.; an MSDS for this graffiti remover is shown in Appendix A. The second was the graffiti remover formulated by IRTA which contained 50% acetone and 50% benzyl alcohol by volume.

Figure 5-7. Graffiti resistant coatings on concrete with graffiti

Figure 5-8. Graffiti resistant coatings on stucco wall with graffiti

Figure 5-9. Graffiti resistant coatings on granite with graffiti

The Surtec graffiti remover worked well in removing the graffiti from three of the coatings on the concrete wall. It did not remove graffiti very well from the PWS-15/PWS-8 silicon coating. IRTA's graffiti remover worked well in removing graffiti from all four coatings on the concrete wall. The Surtec graffiti remover worked very effectively in removing the graffiti from the three coatings on the painted stucco. IRTA's graffiti remover did not work well on the graffiti on this surface. The Surtec graffiti remover worked acceptably in removing the graffiti from the coated granite. It worked well in removing graffiti from the Monopole coating on the granite. It did not leave a shadow on the granite surface coated with the Surtec Coating. IRTA's graffiti remover worked a little better than the Surtec graffiti remover in removing the graffiti from the granite coated surfaces. IRTA gave samples of these two graffiti removers to the manager of the Bill Graham Concert Hall for field testing. Pictures of the substrates after the graffiti removers were tested are shown in Figures 5-10 and 5-11. IRTA gave samples of these two graffiti removers to the manager of the Bill Graham Concert Hall for field testing and that testing is still underway.

Figure 5-10. Graffiti resistant coatings on concrete after graffiti removal

Figure 5-11. Graffiti resistant coatings on granite after graffiti removal

IRTA applied the Coval nanotechnology Anti-Graffiti Coat to the concrete and granite surfaces at a later date. A primer/sealer was applied to the concrete wall and the Coval topcoat was applied to both

substrates. In the case of the granite, the coating was applied to half of the granite sample and the other side was left bare. IRTA waited about one month for a full cure. IRTA applied the same blue and black spray paint in layers to both substrates and allowed it to cure overnight. A picture of the concrete wall with the coating and graffiti is shown in Figure 5-12. A similar picture of the granite is shown in Figure 5-13. After the one month curing process, the Coval coating discolored or stained both the concrete and the granite and it would not be acceptable to many users for this reason. It was carried through the testing process, however.

Figure 5-12. Coval coating on concrete wall with graffiti

Figure 5-13. Coval coating on granite with graffiti

For the testing, in this case, IRTA used the three IRTA formulated general graffiti removers to remove the graffiti. The graffiti was removed fairly well from the Coval coating on the concrete using IRTA's graffiti removers. The graffiti was removed more easily from the Coval coated side of the granite so it would be effective in protecting this surface. Because it discolored the substrate, however, it would not likely be widely adopted for masonry surfaces.

5.2.3.2.Graffiti Resistant Coating Tests on Fiberglass Panel

IRTA tested two of the graffiti resistant coatings applied to a fiberglass panel used on the insides of the Muni trains. The Muni train people applied the Monopole coating to one half of a fiberglass panel and the other half was left bare. Blue and black spray paint was applied to both sides of the panel heavily and allowed to cure overnight. The following day, IRTA and the Muni representative used graffiti removers formulated by IRTA to remove the graffiti from both sides of the panel. The results indicated that the graffiti removers removed the graffiti more easily from the side of the panel that was not coated with the graffiti resistant coating. This is consistent with other testing IRTA conducted on several different types of substrates.

IRTA and the Coval representative also applied the Coval coating to half of the same type of fiberglass panel used on the MTA trains. A picture of the panel with the graffiti is shown in Figure 5-14. The other side was left uncoated. After one month of curing, graffiti was applied to both sides of the panel and allowed to cure overnight. The blue and black spray paint were used and the black Sharpie marker and silver paint marker. The next day, the IRTA formulated graffiti removers were used to remove the graffiti. The results indicated that it was equally difficult to remove the graffiti from the coated side than from the uncoated side. Again, this is consistent with the results of other such tests on various substrates.

Figure 5-14. Coval coating on fiberglass panel with graffiti

5.2.3.3.Graffiti Resistant Coating Tests on Street Signs

IRTA and Monopole applied the graffiti resistant coating to a stop sign and the coating did not maintain the reflectivity. IRTA discussed the issue with other suppliers and they confirmed that, in general, graffiti resistant coatings do not maintain reflectivity of the signs. This is obviously a safety problem and IRTA concluded that such coatings could not be used on signs.

Coval indicated that their coating, because it is a nanocoating, does maintain the reflectivity of street signs. The theory is that the extremely small particles of the coating allow the reflective undersheet to show through the very thin coating. Coval and IRTA applied the Coval Metal Coat to half of several different street signs and it was verified that the reflectivity was maintained. Spray paint and marker

were applied to both sides of the sign and they were allowed to cure overnight. Pictures of graffiti on two of the street signs are shown in Figure 5-15 and 5-16.

Figure 5-15. Coval coating on no parking sign with graffiti

Figure 5-16. Coval coating on stop sign with graffiti

IRTA attempted to remove the spray paint and marker with packaging tape to determine if the coating behaved like the 3M film and kept the graffiti on the surface of the coating barrier. None of the graffiti was removed with the packaging tape so the graffiti actually penetrates the coating. At a later time, IRTA placed a postal sticker on both sides of the sign and allowed it to cure overnight. The postal sticker could not be pulled up from the surface. An aggressive IRTA formulated graffiti remover was able to remove the graffiti and the postal sticker from the coating. This is similar to the behavior exhibited by the Vandal Guard film; in that case as well, an aggressive graffiti remover was needed to remove the graffiti from the film. The results of the testing indicated that the Coval coating could be used to protect street signs.

5.2.3.4.Graffiti Resistant Coating Tests on Lighting Fixture

One of the problems encountered by the MTA-Train people is that taggers put graffiti on the light fixtures that protect the light on the ceiling of the trains. A picture of one of the light fixtures, which is pebbled with raised and lowered areas and is made of a plastic material, is shown in Figure 5-17. Although spray paint is usually the graffiti of choice, marker is sometimes found on the fixtures as well. Most graffiti removers cannot be used on the light fixture because they etch the surface of the plastic. IRTA and the MTA-train people applied the Monopole coating to a light fixture. The coating did protect the fixture from etching by the remover but an aggressive graffiti remover was needed to remove the spray paint and marker which were allowed to cure overnight. In addition, the graffiti remover needed to be scrubbed with a brush to penetrate the lowered pebbled areas. The MTA representative indicated that this is not possible because the fixtures would have to be removed to be scrubbed and this would take too much time. The coating was judged to be a poor option for the fixture as a result.

Figure 5-17. Lighting fixture with pebbled surface

5.2.3.5.Cost Analysis of Graffiti Resistant Coatings on Masonry Surfaces

IRTA analyzed and compared the cost of three of the coatings for concrete and granite surfaces. These included the Monopole, Surtec and PWS-15/PWS-8 coatings. IRTA did not include two of the coatings, the BDC and Coval coatings, in the analysis since they discolored the masonry. In general, the graffiti resistant coatings are designed to last indefinitely and are defined as non-sacrificial so they do not have to be removed and reapplied. Graffiti could be removed from all of these coatings either with the Surtec or IRTA formulated graffiti removers so the costs of removal were not considered in the cost analysis. The cost of using the coatings is therefore based on the initial costs of purchasing and applying the coatings.

For the cost analysis, IRTA compared the cost of using the coatings on a square building with outside dimensions of 100 feet by 100 feet. When coating a building surface for graffiti protection, the coating is generally applied only to the bottom six feet or so of the building. This follows from the fact that taggers generally apply graffiti below a height of about six feet. Because only the bottom six feet of the building is coated, it is important that the coating not discolor or stain the masonry for the building appearance but also because the tagger could tag higher up if it is obvious a coating is on the building.

The four sides of the building with dimensions of 100 feet by six feet would require application of a coating. The total square footage needing coating is 2,400 square feet.

5.2.3.5.1.Monopole Coating

The Monopole system consists of three coatings. One coat of Aquaseal ME12 is needed to seal the surface of the masonry from moisture. It has a coverage rate of 60 to 90 square feet per gallon. The retail price of the coating is $35 per gallon. The coating would ideally be sprayed on but could be rolled. One or two coats of Permashield Base Coat are needed; if the surface is relatively smooth, only one coat would be necessary. The coverage for this coating is 200 to 250 square feet per gallon and the price is about $56 per gallon. Two coats of the Permashield Premium, the graffiti resistant coating, are required. The coverage is 200 to 250 square feet per gallon and the price is $151 per gallon. Both the base coat and topcoat can be rolled on.

For the cost analysis, IRTA assumed the midpoint for the coverage of each of the three coatings. On this basis, 32 gallons of the ME12 would be required at a cost of $1,120. For the base coat, IRTA assumed only one coat would be necessary. The total cost of the base coat for the operation is $597. Two coats of the topcoat are required and the total cost of these two coats is $3,221. The total cost of the coating purchases amounts to $4,938.

5.2.3.5.2.Surtec Coating

This system consists of a primer called Bondcoat and a topcoat called Graffiti Barrier VOC. One or two coats of the Bondcoat are necessary, depending on how porous the substrate is. For analysis purposes, IRTA assumed that only one coat is needed. For concrete, this coating has a 700 to 800 square feet per gallon coverage and the cost of the coating is $37 per gallon. The coating can be sprayed or rolled on. For the Graffiti Barrier VOC coating, two coats are required. The coverage of this coating is 400 to 600 square feet per gallon and the price is $121 per gallon. This coating can be rolled on.

For the cost analysis, IRTA again assumed the midpoint of the coverage. On this basis, the cost of the Bondcoat would amount to $118. The cost of the Graffiti Barrier VOC coating, assuming two coats are needed, is $1,162. The total cost of the coating system is $1,280.

5.2.3.5.3.Professional Products Coating

As mentioned earlier, this coating slightly discolored the concrete wall used for testing but it did not seem to discolor the granite. The staining on the concrete was only slight and might be acceptable. This would have to be determined by the user on a case-by-case basis by testing the coating on small patch.

The system consists of two coatings, the PSW-15 and PSW-8. One coat of each of the coatings is required for concrete. Coverage for both of the coatings ranges from 135 to 150 square feet per gallon, depending on the type of concrete. The price of both coatings is $85 to $90 per gallon. The coatings should be sprayed on; for the testing, however, IRTA rolled the coatings on.

For the cost analysis, IRTA assumed that one coat each of the PSW-15 and PSW-8 are required. Assuming the midpoint of the coverage and the cost, the cost of the PSW-15 would amount to $1,474. The cost of the PSW-8 would be the same. On this basis, the total cost of the coatings would be $2,948.

5.2.3.5.4.Summary of Coating Cost Comparison

Table 5-1 summarizes the cost comparison for the three different types of coatings. The cost analysis only considers the initial cost to the user for purchasing the coatings. The labor costs of applying the coatings could be very different. For the Monopole coating system, for instance, the ME12 should ideally be sprayed. The Professional Products coatings should also be sprayed. Spraying the coatings on is generally faster but the transfer efficiency of the coating will be significantly lower than the transfer efficiency achieved with rolling. This implies that more of the coatings would have to be purchased if they are sprayed. Four coatings need to be applied for the Monopole system, three for the Surtec system and two for the Professional Products system. More labor time is generally required for applying more coatings.

Table 5-1
Cost Comparison of Graffiti Resistant Coatings for Masonry

Coating	System	Cost
Monopole	ME12 (one coat)	$1,120
	Permashield Base Coat (one coat)	$597
	Permashield Premium (two coats)	$3,221
	Total Cost	**$4,938**
Surtec	Bondcoat (one coat)	$118
	Graffiti Barrier VOC (two coats)	$1,162
	Total Cost	**$1,280**
Professional Products	PSW-15 (one coat)	$1,474
	PSW-8 (one coat)	$1,474
	Total Cost	**$2,948**

The values of Table 5-1 demonstrate that the cost of purchasing the coatings is lowest for the Surtec system. The Monopole coating system purchase cost is the highest. Again, depending on the labor cost of applying the coatings, the total costs or using the systems may differ substantially from those in the table.

5.2.3.6.Cost Analysis of Coating and Film for Street Signs

In some cases, as discussed earlier, agencies may have their own dedicated sign shops and may not be concerned about the warranty. In such cases, these agencies could use the Coval coating which performed well or the Vandal Guard film rather than the 3M film. IRTA evaluated the cost of using the Coval coating for sign protection and compared the cost to the cost of using the 3M and the Vandal Guard film.

When agencies contract with sign shops, the sign shops make the signs according to the agency specifications. The sign shops are equipped to apply the sheeting and films but they are not equipped to apply a coating. Using a coating would violate the warranty as well so sign shops would likely not be willing to apply a coating. Furthermore, the sign shop would have to purchase a coating booth and spray equipment to apply the Coval coating; they would have to obtain a permit for the spray booth and learn a whole new process.

IRTA contacted a company in Monrovia, California that routinely performs metal finishing contract jobs. Information on the company, called Jan-Kens, can be accessed on their website at www.jankens.com. IRTA asked the company to provide an estimate for coating street signs based on the MSDS for the coating and information about the process. A Jan-Kens representative indicated that the company would charge between about $2.75 and $3.00 per square foot to coat the signs.

As discussed earlier, the cost of a typical stop sign to an agency is about $35. A sign shop will charge an additional $15 or $16 to apply the film to the sign. IRTA measured a stop sign which is an octagon with a diameter of about 30 inches. There are four cut-outs of 8 inches by 8 inches. The total area of the sign is roughly 5.36 square feet. Assuming the midpoint of the Jan-Kens cost estimate, the cost of coating the sign would be $15.41. The agency contracting with Jan-Kens would also have to pay for the Coval coating. The supplier provided a cost of $246 per gallon for the coating and the coating has a coverage rate of 900 square feet per gallon. On this basis, the cost of the coating for the street sign would be $0.27 per square foot or a total of $1.47. The total cost of coating the sign would amount to $16.88. This is slightly higher than the cost of using the 3M film. The lowest cost option, if the warranty is not an issue, is to use the Vandal Guard film.

VI. Specific Graffiti Management Challenges

During this project, IRTA collaborated with a number of different agencies to test alternative management methods. Some of the problems each of the agencies identified were general and some were specific. The general problems pointed IRTA to finding and testing alternative management methods like blasting technologies, alternative graffiti removers and methods of protecting surfaces like graffiti resistant coatings or films. In the earlier sections of this document, IRTA examined these alternative methods in a range of different applications to generalize their applicability for solving certain types of problems. This section focuses on more specific problems experienced by the agencies participating in the project and also, in a few cases, by other organizations with graffiti problems. The specific challenges and the testing results are described below.

6.1.Handrail Graffiti

The MTA-Structures group has several kiosks and other buildings that have escalators for transporting people down to the underground trains. The handrails are often defaced, primarily with spray paint but also, sometimes, with marker. This is unsightly and it must be managed by the staff. A picture of a handrail on an escalator and a closeup picture of the handrail are shown in Figure 6-1 and 6-2.

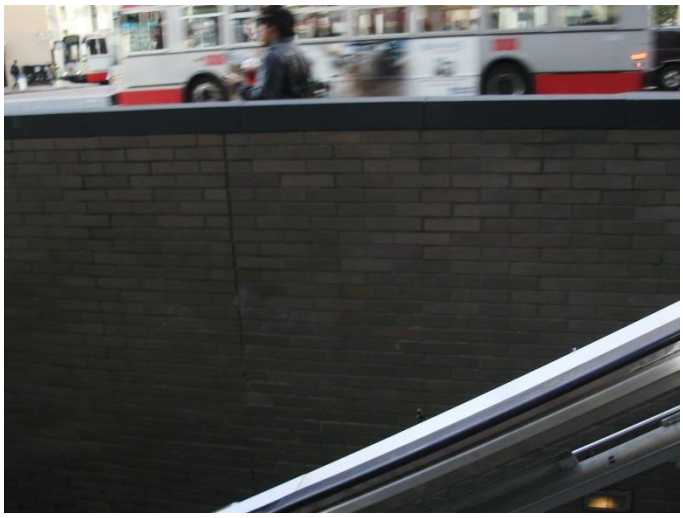

Figure 6-1. Rubber handrail on escalator

One method of dealing with the handrail graffiti is to paint over the graffiti with black paint. This may be somewhat inconvenient because the escalator would have to be cordoned off while the paint dries. The other method is to use a graffiti remover. The disadvantage of this approach is that nearly any graffiti remover that can remove spray paint and marker will likely also damage the rubber of the handrail to some extent. The damage may be minimal but, even so, it may shorten the life of the handrail which would have to be replaced earlier than if it were painted over. The handrails are apparently fairly expensive.

Figure 6-2. Close up of rubber handrail

Even with the disadvantage of the graffiti remover, IRTA did conduct testing to see if graffiti removers could effectively remove heavy graffiti from the handrail. The MTA-Structures people wanted to use a very durable spray paint called Kilz primer to see if a graffiti remover could remove it. IRTA conducted testing with more traditional spray paint and marker and also with the Kilz primer after one week of curing. A picture of the handrail with the graffiti is shown in Figure 6-3. All three of IRTA's general graffiti removers worked but the best graffiti remover for removing the graffiti was the blend of 50%Soy Gold 2500/50% benzyl alcohol. Again, the limitation of using a graffiti remover is that the life of the handrail could be shortened.

Figure 6-3. Rubber handrail with graffiti

6.2.Grout Graffiti

The MTA-Structures group has an ongoing problem with graffiti on the tile walls in certain structures housing the escalators and staircases for descending to the underground trains. The tile is slippery so the graffiti is easy to remove from that surface. In contrast, the graffiti, which is generally spray paint, is very difficult to remove from the grout between the tiles. A picture of the graffiti on the grout is shown in Figure 6-4.

Figure 6-4. Graffiti on grout in underground train structure

IRTA conducted some testing on removing graffiti from grout. IRTA made grout on a small scale and covered it with heavy spray paint which was allowed to cure overnight. IRTA was able to remove the spray paint from the grout fairly readily with all of IRTA's general graffiti removers containing soy, benzyl alcohol and acetone. IRTA took the graffiti removers to the site but was not able to remove the graffiti at all. It turns out that the grout must have been sealed so, in order to remove the spray paint, the clear sealer would have to be stripped off during the graffiti removal. Either the dry ice or the crushed recycled glass blasting systems could work effectively to remove the graffiti but IRTA did not test them. If one or both of the blasting technologies were successful, it might be necessary to reapply the grout and sealer. Perhaps a better option would be to not seal the grout. In that event, a graffiti remover would be able to remove the spray paint as demonstrated in IRTA's testing.

6.3.Brick Building Graffiti

MTA-Structures is responsible for maintaining the outside of many buildings housing the train entrances. In general, these buildings are made of a range of different types of masonry products. The group purchased the Monopole graffiti resistant coating and planned to apply it to a brick building in San Francisco. The application and testing was not completed by the time this report was finalized. From the tests IRTA conducted at the Port of San Francisco, it was expected that this option would work well.

6.4. Adhesive Residue and Stickers

MTA-Structures uses graffiti removers to remove residue from stickers and other adhesive and stick material in their structures. IRTA provided the Structures staff with IRTA's three general graffiti removers containing soy, benzyl alcohol and acetone over the course of the project and the staff indicated they worked well on stickers and adhesive residue.

6.5.Stickers on Inside Train Surfaces

The MTA-Trains group has a significant problem with stickers on the inside surfaces of the trains and did not have an effective compliant graffiti remover for removing them. IRTA worked on developing a

specific graffiti remover for this application. The blend of 80% Soy Gold 2500/20% acetone discussed earlier did an effective job at removing the stickers in scaled up testing by the MTA-Trains staff. The staff indicated that the graffiti remover was also a good general graffiti remover.

6.6.Train Light Fixtures

The MTA Trains have light fixtures along the top of the trains to protect the lights. The fixtures are made of a plastic material and they are pebbled with raised and lowered areas on the side facing outside. The side facing the lights is smooth. A picture of the outside of one of the light fixtures IRTA used for testing was shown in Figure 5-17 and Figure 6-5 shows the smooth side facing the lights. The MTA-Trains people must remove spray paint and sometimes marker from these fixtures routinely. They must clean the trains quickly so they must have a method of cleaning the fixtures quickly in place without removing them.

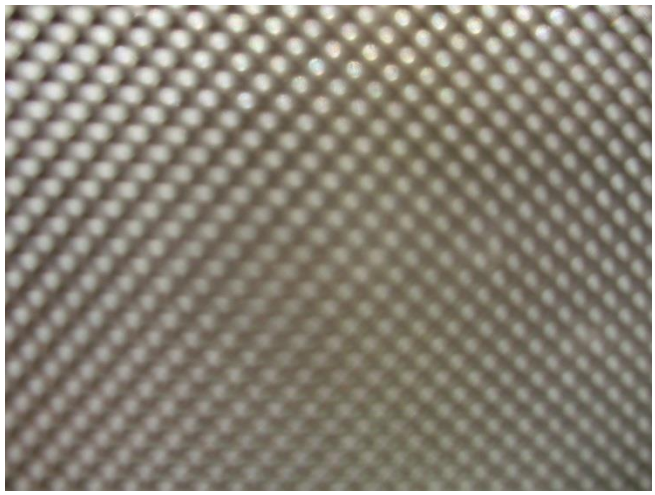

Figure 6-5. Smooth side of lighting fixture

IRTA conducted a significant amount of screening testing on the fixtures to try to find a graffiti remover that would be effective in this application. Many of the ingredients IRTA used in the graffiti removers, including acetone and benzyl alcohol, crazed the plastic of the fixture. Soy did not craze the plastic but it was not aggressive enough to remove the graffiti with a cloth. In addition, it cannot alone remove marker.

As discussed in Section V, IRTA and the MTA-Trains people decided to coat the fixture with a graffiti resistant paint. IRTA used two of IRTA's general graffiti removers and was able to remove the spray paint but only with scrubbing with a brush which the MTA staff cannot do. The best option for the fixtures is to turn them over in place so the smooth side is facing downward. IRTA easily removed graffiti (spray paint and marker) from the smooth side of the fixture with a cloth without scrubbing using IRTA's gentle graffiti remover, the blend of Soy Gold 2500 and rubbing alcohol. In order to turn over the fixtures, the MTA-Trains people need permission and have not been able to obtain it yet.

6.7.Street Signs

Methods of protecting street signs and graffiti removal methods were discussed in detail in Section V. Several of the project participants are responsible for routine graffiti removal from street signs. IRTA developed a gentle graffiti remover for removing graffiti from street signs and films or the nanocoating can be used to protect them. For the 3M film, the graffiti can largely be removed with packaging tape with only a small amount of gentle graffiti remover. For the Vandal Guard film and the nanocoating, IRTA's more aggressive graffiti removers can be used.

IRTA provided demonstrations of the gentle graffiti remover and the films in San Francisco for the interested parties. The MTA-Structures people and staff from the Port of San Francisco attended. IRTA provided demonstrations. Both groups ordered street signs with the 3M film after the demonstrations. The Simi Valley staff tested IRTA's gentle graffiti remover for removing graffiti from bare signs and found it to perform acceptably. If heavy scrubbing is necessary, however, the screen printing will be removed with any graffiti remover. The Simi Valley people ordered several street signs with the 3M film and have field tested them for several months. They have not had to remove a significant amount of graffiti from the signs yet. They did indicate that the 3M film is an advantage for stickers which can be pulled from the surface easily.

6.8.Multisurface Graffiti

The Port of San Francisco has an extensive range of surfaces with graffiti on them they must control. The surfaces are wood, masonry, metal, fiberglass, glass and plexiglass. At the beginning of the project, the Port indicated they were interested in finding blasting systems that minimized waste generation and alternative graffiti removers. One of the other participants, MTA-Structures is also interested in exploring blasting systems that could help with various types of graffiti removal from a range of surfaces.

After the demonstrations of the blasting systems, the Port investigated first renting and then purchasing both systems, the dry ice and crushed recycled glass systems. The Port cannot use a vendor unless the vendor is approved by the City of San Francisco and that approval process is apparently underway. The Port staff believe the systems would help greatly with much of the graffiti removal they are required to do.

IRTA provided larger quantities of some of IRTA's graffiti removers to the Port for testing in place of the graffiti removers they are using today. These included two of IRTA's general graffiti removers composed of 50% Soy Gold 2500/50% benzyl alcohol and 50% Soy Gold 2500/50% acetone. IRTA also provided the sticker remover composed of 80% Soy Gold 2500/20% acetone to the Port for testing. The Port tested the graffiti removers on a variety of surfaces and indicated they all worked very well.

6.9.Glass Graffiti and Etching

As mentioned earlier, many of the project participants have problems in controlling graffiti on glass and plexiglass. In addition, many taggers etch the glass which makes it very unsightly. IRTA conducted testing of IRTA's graffiti removers for removing spray paint and marker from glass. Because it is a smooth uniform surface, graffiti is relatively easy to remove. Plexiglass graffiti removal is more problematic because some graffiti removers can etch the plexiglass if they are too aggressive. IRTA's gentle graffiti remover is effective in removing spray paint and marker from the glass.

If the glass is etched with either diamond tipped tools or with acid, the glass is left with scratches. If there are holes or breaks in the glass, the only option is to replace it. If the glass is scratched, it can be repaired. IRTA did not test this option but contacted a company called RapidRenu to discuss the repair and other prevention options. In general, four panes of glass with scratches can be repaired for the price of replacing one pane.

RapidRenu uses a dry grinding process for repairing the glass which does not generate as much waste as the wet grinding process used by some companies. Dry grinding involves shaving off 1/1000th of an inch of glass from the damaged part of the glass. Removing the scratches strengthens the glass by removing the site (scratch) of stress and weakness. The company has a job minimum of $350 and generally charges between about $100 and $250 to repair both sides of one pane of glass.

The company also offers two options for prevention. The first option is to use sacrificial films to protect the glass. IRTA discussed this option earlier in the last section. The taggers will not see the film on the surface and, if they etch only part way in, they may damage only the film and not the glass. RapidRenu charges $11 per square foot for removal and replacement of the film. If the glass is in a location where there is heavy graffiti activity, this would probably not be a good option because it would be expensive.

The second option may be more cost effective in heavy tagger activity areas. RapidRenu will apply a coating to the glass that is transparent. An MSDS for the waterborne coating, called HardCoat-2G/Glass Hard Coat, is shown in Appendix B. Taggers do not realize there is a coating on the surface and they may scratch only the surface of the coating and not penetrate to the glass. RapidRenu grinds down the damage on the coating and reapplies it over the existing coating. There is a minimum of $350 per job but the cost of this option is lower than for the film, at $7 per square foot.

IRTA tested the RapidRenu coating on glass and it does protect the glass to a large extent. It cannot protect against acid or diamond tip tool etching if the tagger etches deeply enough. In many cases, however, they will not be aware the coating is on the glass and they will not etch this deeply. The coating is very hard and will protect against steel tools. A picture of the glass with the transparent coating is shown in Figure 6-6.

Figure 6-6. Glass with transparent film

6.10. Concrete Block Surface Graffiti

Virtually all the agencies IRTA worked with during the project need to remove graffiti from various types of masonry surfaces on an ongoing basis. This is a big issue because the other options are to paint over the masonry which is very unsightly, to use a graffiti resistant coating or to use an aggressive blasting system. Some users do not want to purchase and apply graffiti resistant coatings and may not want to purchase a blasting system.

In general, when a graffiti remover is used to remove graffiti, which is largely spray paint, from bare masonry, the user relies on a high pressure water spray system to fully remove the graffiti and the graffiti remover after it has acted. Again, the water from the spray system must be collected and not released to the land without analysis or the storm water, as discussed earlier.

As described in Section III, IRTA tested several commercial graffiti removers and two of IRTA's graffiti removers for removing graffiti from a concrete wall at the Port of San Francisco. Some of the commercial graffiti removers and both of IRTA's removers worked well and rinsed well with the high pressure water spray that followed.

IRTA conducted testing during this project to formulate a low-VOC, low toxicity graffiti remover for removing graffiti from concrete block. This type of masonry, along with the bare granite used for the San Francisco City Hall and the Bill Graham Concert Hall, is the most difficult graffiti removal challenge. IRTA tested a variety of different formulations based on soy, benzyl alcohol, acetone and other ingredients on concrete block containing spray paint. Several of the formulations were capable of completely removing the spray paint from the block but they always left a residue on the concrete block, presumably from one or more of the chemicals used in the formulations. In effect, they changed the look of the block at the location of the graffiti where it was a different color. An examples of this effect is shown in Figure 6-7. IRTA was not able to solve this problem by the end of the project.

Figure 6-7. Residue remaining on concrete blocks

VII. Health and Environmental Issues and Regulations

This section presents information on the regulations that affect the use of management technologies used in graffiti removal. Some of these regulations were discussed earlier to set parameters for the alternatives investigation and testing. They are repeated here briefly for completeness. The section discusses some of the cross-media transfers that might occur when certain technologies are used and the worker exposure issues that arise as a result of using some of the methods. The discussion focuses on three categories. First, the section addresses the toxicity and worker exposure that results from the use of certain ingredients in graffiti removers and graffiti resistant coatings. Second, the section provides information on the air regulations, including VOC limits for graffiti removers and graffiti resistant coatings. Third, the section summarizes the discharge and hazardous waste regulations that affect the use of blasting systems and addresses the certification and permitting requirements for the systems.

7.1.Toxicity and Worker Exposure

Suppliers often use toxic ingredients in their products as part of the formulation. Most agencies try to screen out these products but this is often a problem for two reasons. First, MSDSs do not always list all of the ingredients in a product. Second, even some of the listed ingredients may not be flagged because they don't yet appear on any of the lists that would warn agency personnel that the material is toxic. IRTA discusses some of the materials that are used in graffiti removers and in graffiti resistant coatings that may pose a toxic risk to workers and community members. IRTA also addresses another toxic exposure issue that results from the use of blasting systems used on masonry surfaces.

7.1.1.Graffiti Removers

Part of the justification for conducting this project is that many of the graffiti removers used today contain toxic components that can pose risks to workers and community members. Two solvents in particular, methylene chloride and NMP, are commonly used in graffiti removers. Methylene chloride is a carcinogen and it is a listed by EPA as a Hazardous Air Pollutant (HAP), it is listed by CARB as a Toxic Air Contaminant (TAC) and CARB regulations forbid the use of the solvent in graffiti removers. Methylene chloride is also listed on California's Proposition 65. The Occupational Safety and Health Administration (OSHA) developed a very stringent regulation on methylene chloride several years ago; it establishes a worker exposure limit of 25 ppm with an action level of 12.5 ppm. It also requires users of methylene chloride to conduct medical surveillance on workers using the material. In spite of these regulations, several suppliers do include the chemical in graffiti removers. NMP is a reproductive and developmental toxin. It is listed on California's Proposition 65 and is classified as a VOC. NMP is used extensively in graffiti removers as a "green" alternative to methylene chloride.

Graffiti removers containing either methylene chloride or NMP should not be used because they pose a danger to workers and community members. There are other materials in some graffiti removers that also pose a toxic risk and agencies should demand information from suppliers on all the ingredients the products contain so they can screen out those with toxic components. During this project, IRTA developed alternatives that contain ingredients that are low in toxicity. IRTA identified a few commercial graffiti removers that contain ingredients that are low in toxicity but the MSDSs for many commercial graffiti removers do not list all the ingredients in a formulation. In several of the MSDSs for the products IRTA discussed earlier, a very small fraction of the graffiti remover ingredients is

characterized on the MSDSs. Again, this information is needed so the agency can be assured that they contain no very toxic ingredients.

Some graffiti removers contain surfactants which makes them water rinseable. Nonyl phenol ethoxylates are commonly used in the formulations. These materials are endocrine disruptors and agencies should not use formulations containing them. The alternatives that are generally better are linear alcohol ethoxylates.

7.1.2.Graffiti Resistant Coatings

Coatings of all kinds often contain toxic solvents and graffiti resistant coatings are no exception. Some of the graffiti resistant coatings tested by IRTA contain solvents that are exempt from VOC regulation in parts or all of California. These chemicals have potential toxicity problems.

In general, the exemption process works this way. EPA assumes that chemicals are VOCs unless they are deemed exempt from VOC regulation. EPA makes this decision based solely on the reactivity of the material in the lower atmosphere and whether it is capable of forming smog. EPA does not consider toxicity in this evaluation. Once EPA deems a material exempt, the suppliers generally petition CARB and the local air districts in California to exempt their chemicals as well. The California agencies have the option of considering toxicity in the exemption decision.

California has the most stringent VOC regulations in the nation. When a chemical is deemed exempt in California, it can be used extensively in products to satisfy the VOC restrictions. In other parts of the country, where there are fewer VOC restrictions, exempt chemicals are not used widely or, in some cases, at all. Suppliers would be able to formulate products that meet the limited VOC regulations with several different VOC solvents. In contrast, when a chemical is exempted in California, the action literally promotes the use of the chemical and it is used widely. Two chemicals that are exempt in all or part of California that are used in graffiti resistant coatings are discussed below.

7.1.2.1.TBAC Based Coatings

One of the coatings tested by IRTA, the Coval Coating, relies on two different solvent carriers, depending on where it is used. Both the BAAQMD and the SCAQMD explicitly exempt methyl acetate from VOC regulations. The Coval coating has one version with this carrier solvent. The SCAQMD exempts tert-butyl acetate (TBAC) from VOC regulations in SCAQMD Rule 1113 as indicated earlier. This exemption applies because graffiti resistant coatings are considered to be Industrial Maintenance Coatings. The narrow exemption in the rule does allow the use of TBAC in the jurisdiction of SCAQMD. In contrast, there is no limited exemption for TBAC in the BAAQMD rule that applies to Industrial Maintenance Coatings. Most of the air districts in the rest of the state also exempt TBAC for use in these coatings.

TBAC forms a metabolite, tert-butyl alcohol, which is a carcinogen. The Office of Environmental Health Hazard Assessment (OEHHA) is the official agency in California that evaluates the toxicity of substances. OEHHA has examined the toxicity of TBAC and has concluded that it is a potential human carcinogen. Several years ago, when TBAC emerged and was deemed exempt from VOC regulations by EPA, the Hazard Evaluation System and Information Service (HESIS) developed information on the risk of TBAC to workers exposed to the chemical at the Permissible Exposure Limit (PEL) of 200 ppm established by OSHA. Based on OEHHA's toxicity data, HESIS indicated the risk to a worker at the PEL would range from 74,000 in one million to 380,000 in one million. This is a very high risk. The SCAQMD has recently used

the OEHHA toxicity data to model the risk posed by TBAC to workers, community members and off-site workers. Using assumptions about a roof coating operation, the risk is very high for all three receptors.

Users of graffiti resistant coatings for concrete or metal (street signs) should not use the version of the Coval coating that contains TBAC regardless of the area of California they intend to apply it. Since TBAC is not exempt in the BAAQMD jurisdiction, the Coval coating containing TBAC would not comply with the VOC limits there in any case. In other parts of the state, where TBAC is exempt, users should select only the version of the coating containing methyl acetate.

7.1.2.2 PCBTF Based Coatings

Parachlorobenzotrifluoride (PCBTF) was deemed exempt by EPA many years ago. Virtually all of the air agencies in the state also exempted it for all applications. Many companies began formulating products, particularly coatings, with the solvent to meet the low VOC limits. IRTA opposed the exemption at the time based on the structure of the molecule which contains a benzene ring with a chlorine substituent. There were no chronic toxicity data on PCBTF and the toxicity data that existed did not indicate the chemical had a toxicity problem.

Based on a letter written by IRTA many years ago, the National Cancer Institute decided to conduct toxicity tests, including a two-year animal carcinogenicity test, on the chemical. The testing has been completed and the pathology is currently underway. The results of the testing should be available in 2015. If the results indicate PCBTF is a carcinogen, the exemption from VOC regulation in many regulations may have to be revoked.

Two of the graffiti resistant coatings tested by IRTA for masonry products contained PCBTF as the carrier solvent. These include PWS-8/PWS-15, a silicone based coating and BDC-4320. As indicated in Section V, the BDC-4320 discolored the concrete.

7.1.2.3.Other Coating Potential Issues

There is increasing concern recently about polyurethane coatings which are two-part coatings. These coatings cure through combining Part A of the coating with Part B. Part B of these coatings generally contains isocyanates. The coatings form a hard resin when they cure and there is likely little, if any, isocyanate left at that time. During the coating application operation, when the parts are being blended, the workers could be exposed to the isocyanates.

Three of the graffiti resistant coatings IRTA applied to the masonry surfaces are polyurethane coatings which contain hexamethylene diisocyanate. These include the Monopole coating, the Surtec coating and BDC-4320. The Monopole and Surtec coatings are waterborne and the BDC-4320 contains PCBTF as discussed above.

7.1.3.Blasting Systems Use on Masonry Substrates

Blasting systems are often used to remove graffiti from concrete walls, sidewalks, benches and walkways or from granite, concrete block or stucco. Virtually all masonry substrates contain some level of silica which can cause lung disease. Blasting with a dry technology will release some of these silicates and the workers using the technology could be exposed to it. Blasting with a wet technology will also

release silicates but, because there is water in the blasting media, the worker exposure to the silica is likely to be lower.

7.2.VOC Regulations

As discussed earlier, the VOC limits for products used in California are generally much lower than they are in other parts of the country. VOC regulations affect both graffiti removers and graffiti resistant coatings. Although these were discussed earlier, they are repeated here briefly.

7.2.1. Graffiti Removers

CARB is the agency that regulates the air emissions from consumer products in California. The current VOC limit for graffiti removers in CARB's Consumer Product Regulation is 30%. For aerosol graffiti removers, the VOC content limit is higher, at 50%.

As discussed earlier, many of the graffiti removers IRTA encountered during this project do not meet the VOC content limits established by CARB. CARB is planning to conduct a survey of virtually all the consumer products they regulate over the next year or so. Part of the reason many of the graffiti removers are noncompliant is that CARB does not have a comprehensive list of the companies that supply products in or to California. Several of the suppliers IRTA contacted during the project seemed unaware that there even were VOC regulations on graffiti removers. In the new survey CARB is conducting, perhaps they will identify more of the product suppliers.

As mentioned earlier, CARB has an exemption in the regulation for LVPs or Low Vapor Pressure materials. The local air districts which have jurisdiction over stationary sources do not have the same exemption. The effect of the CARB exemption is that many more materials can be used to meet the VOC limits in the consumer product regulation than in other types of products. Some time ago, CARB agreed to reexamine the definition of LVPs in the regulation and is conducting research projects to determine what that new definition should be. When the results are available over the next few years, many more materials will no longer enjoy an exemption. As a result, a number of the graffiti removers sold in the state that currently meet the CARB VOC limits will have to be reformulated.

7.2.2. Graffiti Resistant Coatings

In the jurisdiction of the SCAQMD, graffiti resistant coatings meet the definition of Industrial Maintenance Coatings and the VOC limit on such coatings is 100 grams per liter; these coatings, in order to meet the VOC limit, are allowed to count TBAC as an exempt chemical. In the jurisdiction of the BAAQMD,TBAC is not exempt for use in Industrial Maintenance Coatings and the VOC limit is higher, at 250 grams per liter. In both air districts, PCBTF is considered to be an exempt chemical for all applications. The coatings IRTA tested during the project generally had VOC content of 100 grams per liter or less.

7.3.Regulations and Requirements for Blasting Systems

Four major issues arise in California with the use of blasting systems. The first issue, which was discussed earlier, is the zero discharge policy for storm water. The second issue is the hazardous waste regulations that affect discharge to land. The third issue is that certain types of blasting systems must be certified by CARB. Each of these issues is discussed briefly below.

7.3.1.Storm Water Regulations

Storm water regulations in most of California forbid the release of any materials whatsoever into the storm water. This zero discharge regulation applies to water and media of all kinds. In certain areas, like the city of San Francisco, for example, discharge is permitted under certain circumstances, because the wastewater goes through a Publicly Owned Treatment Works (POTW) where it is further treated before being released to water bodies. The effect of the zero discharge policy is that water and media must be collected in most areas of the state and cannot be discharged legally.

7.3.2.DTSC Waste Regulations

The spent media from blasting operations should not be discharged to land unless it has been analyzed. DTSC would require the generator to conduct an aquatic toxicity test to determine if the material is classified as hazardous waste in California. The material would need to be collected after blasting. Even if the blasting material itself is not considered hazardous waste, it could be considered hazardous waste by reason of the components it has removed. Perhaps the best option is to collect the spent media; that way, the aquatic toxicity test does not need to be conducted. The spent material should be disposed of properly as California only hazardous waste or RCRA hazardous waste as appropriate.

7.3.3. CARB Certification

CARB requires abrasive blasting materials to be certified. Technologies that rely on wet abrasives do not need certification. As a result, the crushed recycled glass, which is used wet, need not be certified. In contrast, the dry ice blasting system does require certification. Part of the certification process involves providing CARB with a sample of the blasting media. In the case of dry ice, this is not necessary so the only action that is necessary is that the device supplier submit the certification paperwork.

7.3.4.Air District Permits

IRTA asked both the SCAQMD and the BAAQMD if their agencies require users to obtain a permit for the dry ice blasting system or the crushed recycled glass system. The BAAQMD indicated the systems did not require a permit. SCAQMD indicated that they would require users of the crushed recycled glass system to obtain a permit but that the dry ice blasting system is exempt from permitting.

VIII. Results and Conclusions

Taggers use various materials like spray paint, marker, stickers and acid or diamond tipped tools to apply graffiti or gouge surfaces like masonry walls, bus benches, fences, picnic tables, lamp posts, parking meters, traffic signs, billboards, glass and plexiglass. Public agencies and private companies spend millions of dollars each year and devote significant resources to controlling the graffiti and/or mitigating its effects. Some of the practices used today for managing graffiti pose risks to workers and community members and some can lead to environmental damage. Alternative methods that are safer for workers and the environment are needed.

During this project, IRTA focused on identifying, developing, testing and demonstrating safer alternative graffiti management methods. IRTA recruited several public agencies to work on their specific graffiti management challenges and several of these are general challenges faced by most agencies and private companies. IRTA worked with the participating agencies to test alternatives in three particular categories. These included:

- Blasting systems
- Graffiti removers
- Protective films and graffiti resistant coatings

The tests of alternatives and the findings for each of these categories are discussed in this section.

Some of the general applications considered during the project can be mitigated by using more than one of the management methods. Some of the methods have limitations for certain applications and this is discussed in the section.

IRTA also evaluated the health and environmental issues associated with using the alternative management methods as part of the project. The results of this investigation are also summarized below.

8.1.Blasting Systems

The blasting systems most commonly employed today for graffiti removal are high pressure water systems combined with a graffiti remover and sodium bicarbonate blasting systems which are referred to as soda blasting. These two technologies generate a large volume of waste material. Because most of California is subject to regulations requiring zero discharge to storm water and waste regulations that prevent disposal of hazardous waste to land, the spent media from these operations must be collected. Alternative blasting systems that minimize or eliminate the amount of waste that is generated are needed.

IRTA investigated and tested extensively two alternative blasting systems. Dry ice blasting eliminates the use of secondary waste altogether and it is most useful for removing light graffiti. It can be paired with a system that relies on wet crushed recycled glass to effectively remove heavy graffiti. The cost analysis IRTA conducted showed that the costs of using the soda blasting system on the one hand and the dry ice and crushed recycled glass system on the other hand are comparable. The strong advantage of using the dry ice and crushed recycled glass systems is that the waste generated in the process is much less and it can be collected more easily and cost effectively.

8.2.Graffiti Removers

As part of the project, IRTA analyzed the characteristics of several commercial graffiti removers used by the project participants and some that are listed by one of the sponsors, the San Francisco DE. IRTA identified toxic components like methylene chloride and NMP in several of the graffiti removers used by the participants. Many of these graffiti removers and some of those listed by the San Francisco DE also did not meet the VOC limits established by CARB in their Consumer Products Regulation.

IRTA conducted testing of eight of the commercial graffiti removers listed by the San Francisco DE that met the CARB VOC limit and that did not contain methylene chloride or NMP. Some of these graffiti removers list very few of the ingredients they contain so it is not clear what other components they might contain which could be toxic or VOCs. IRTA is uncomfortable with not knowing all of the ingredients and, as a result, decided to formulate five additional graffiti removers for testing. These graffiti removers were formulated with ingredients that are low in toxicity and all but one has zero VOC content. Three of the graffiti removers were designed to be aggressive general graffiti removers, one was designed to remove stickers and one was a gentle graffiti remover developed to remove graffiti from sensitive surfaces.

The commercial graffiti removers and four of the IRTA formulated graffiti removers were tested on various substrates to determine their efficacy. Most graffiti removers are not universal but rather, are formulated to work on a particular type of graffiti and/or a specific substrate. The commercial removers and the IRTA formulated removers were tested on various substrates including:

- A concrete wall to represent masonry products
- A hard fiberglass panel used on the inside of trains
- The back of a street sign made of aluminum
- The front of a street sign to represent a sensitive surface

IRTA conducted the tests with heavy and light graffiti in certain cases to maximize the ability of the graffiti removers to perform well.

Table 8-1 shows the commercial and IRTA formulated graffiti removers that performed well for removing some or all of the graffiti on various substrates. Many of the graffiti removers were not designed to remove graffiti from porous substrates like concrete. The two best commercial graffiti removers for this application were Lift Off #4 and Taginator. Two of IRTA's graffiti removers, those containing benzyl alcohol, were also effective on concrete. All of the commercial graffiti removers were effective in removing light spray paint from fiberglass and metal. Many of them were also effective in removing marker from these substrates. The two IRTA graffiti removers containing Soy Gold 2500 were effective in removing heavy spray paint and marker from fiberglass and metal. Only the IRTA graffiti removers could remove the postal stickers from fiberglass and metal. Four graffiti removers, Green Graffiti Remover, United 608 and 627 and IRTA's blend of rubbing alcohol and Soy Gold 2500 were capable of removing light spray paint from street signs without causing damage.

8.3. Films and Graffiti Resistant Coatings

IRTA tested two types of materials for protecting substrates. The first material is films which can be used to protect glass, plexiglass and street signs. The second material is graffiti resistant coatings which can be used to protect masonry surfaces, glass and street signs. Each of these applications is described below.

Table 8-1 Graffiti Removers Effective in Removing Some or All of Graffiti on Substrates		
Graffiti Remover	**Graffiti Removed**	**Substrates**
Green Graffiti Remover	light spray paint, marker	fiberglass, metal, street signs
Lift Off #3	Sharpie marker	fiberglass, metal
Lift Off #4	heavy spray paint, marker	concrete, fiberglass, metal
Hoodlum	light spray paint, marker	fiberglass, metal
United 608	light spray paint, marker	fiberglass, metal, street signs
United 627	light spray paint, paint marker	fiberglass, metal, street signs
SE99	light spray paint, marker	concrete, fiberglass, metal
Taginator	heavy spray paint	concrete
IRTA SG2500/BA	heavy spray paint, marker, stickers	concrete, fiberglass, metal
ITRA SG2500/Acetone	heavy spray paint, marker, stickers	fiberglass, metal
IRTA BA/Acetone	heavy spray paint, marker, stickers	concrete
IRTA SG2500/Rubbing Alcohol	light spray paint, marker	street signs

BA is benzyl alcohol

8.3.1. Protecting Street Signs

IRTA tested a few sacrificial films, one a film designed for glass and another designed for plexiglass. They seemed to perform well. IRTA conducted much more extensive testing of two non-sacrificial films for protecting street signs. The first is a fluoropolymer film made by 3M which is designed specifically to protect street signs. The other, a vinyl material made by Vandal Guard, is intended for use on a range of signage. Most of the sign sheeting used in California is made by 3M and the warranty for the sign would be violated if other film is used over the sheeting. Many sign shops recommend the use of the 3M film and will not apply films that violate the warranty. Some agencies may not care about violating the warranty and, if they make their own signs, they can use the Vandal Guard film which is much less costly than the 3M film.

Graffiti is relatively easy to remove from the 3M film. Some of the spray paint and marker can be lifted from the surface of the film with packaging tape. Postal stickers can be peeled off the film easily. A small amount of graffiti remover can be used to remove the remainder of the spray paint or marker from the film. IRTA's sensitive surface graffiti remover can remove the graffiti effectively.

It is more difficult to remove graffiti from the Vandal Guard film. Aggressive graffiti removers must be used. IRTA's three general graffiti removers effectively removed spray paint, marker and stickers from the film with scrubbing.

IRTA also tested a nanocoating made by Coval for protecting street signs. In contrast to other graffiti resistant coatings, this coating does not dampen the reflectivity of street signs which is a safety concern. Graffiti is more difficult to remove from this coating, similarly to the Vandal Guard film, and aggressive graffiti removers must be used. Commercial sign shops will not apply this coating because it violates the warranty and also because they do not have coating booths or permits for a coating operation. Agencies would have to contract with a coating jobshop to apply the coating or apply it themselves.

Table 8-2 summarizes the results of the tests of the non-sacrificial films on street signs. The Vandal Guard film is much less costly than the 3M film on a per square foot basis. Commercial sign shops generally will not apply it for liability and warranty violation reasons. As a result, the Vandal Guard film is a more attractive option for other types of signage.

Table 8-2
Non-sacrificial Film Results for Street Signs

Film/Coating	Graffiti Removal Method	Cost/Cost Effectiveness	Limitations/ Advantages
3M	packaging tape pull off stickers residual graffiti remover	$1.50/square foot $15 to $16 for a stop sign at a sign shop cost effective if sign lasts about 50% longer	maintains warranty
Vandal Guard	aggressive graffiti remover	$0.58/square foot very low cost	violates warranty commercial sign shops will not apply better option for other signage
Coval Nanocoating	aggressive graffiti remover	$16.88 for a stop sign at a job shop	commercial sign shops will not apply

8.3.2. Protecting Masonry Surfaces

IRTA tested six different types of graffiti resistant coatings during the project. IRTA applied five of the coatings to masonry surfaces. One of the coatings was also applied to a street sign as described above. Two of the coatings were applied to a fiberglass panel and one was applied to glass.

Three of the coatings applied to concrete and granite seemed to work effectively and did not discolor the substrate noticeably. Table 8-3 summarizes the costs of purchasing the three coatings and it does not take into account differences in the labor costs of applying them. In general, aggressive graffiti removers must be used to remove the graffiti from these coatings. The table demonstrates that the lowest cost coating is the Surtec coating.

Table 8-3 Cost Comparison of Graffiti Resistant Coatings for Concrete and Granite		
Coating	**System**	**Cost**
Monopole	three coating system	$4,938
Surtec	three coating system	$1,280
Professional Products	two coating system	$2,948

8.3.3. Protecting Fiberglass Surfaces

IRTA applied two of the coatings, the Monopole Coating and the Coval Nanocoating, to a hard fiberglass panel. Aggressive graffiti removers were required to remove graffiti from the panel and the coatings offered no clear advantage for graffiti removal in this case. The coatings may be useful for protecting other types of plastic surfaces that would be affected by graffiti removers.

8.3.4. Protecting Glass

There are two options for protecting glass from taggers who use acid or diamond tipped tools for etching. One option is to use sacrificial film. The taggers will not see the film and may etch only the film which protects the glass. The film can be torn down and reapplied. Another option is to use a graffiti resistant coating to protect the glass. IRTA applied one of the coatings, HardCoat-2G/Glass Hard Coat, to glass. Again, the tagger will not know the coating is on the glass and may etch only the coating, protecting the glass.

8.4.Summary of Management Alternatives

Several different strategies for managing and controlling graffiti of different types on substrates of various kinds were analyzed during the project. Some of the management methods are appropriate for a number of applications and potential users could choose among them and use the one that is optimal for their needs.

Table 8-4 summarizes the general applications and management options that can be used for graffiti abatement. For masonry surfaces, three different methods can be used depending on the substrate or surface. For sidewalks, walkways and large expanses of concrete, a graffiti resistant coating combined with a graffiti remover are not likely to be appropriate. Graffiti removers and blasting systems are better options. For a high quality granite building, like the San Francisco City Hall, a graffiti resistant coating could be the choice; the other options are appropriate in this instance as well. For street signs, there may be warranty issues for certain non-sacrificial films and graffiti resistant coatings. For other signage, these options are good. For large wood fences, painting over is one option; a less aggressive blasting system, like dry ice blasting for example, might be suitable for wooden piles on piers. For nonporous substrates, like hard fiberglass and other non-sensitive surfaces, a graffiti remover is the best option. For glass, a graffiti remover can be used for general graffiti and sacrificial films or graffiti resistant coatings can be used to possibly prevent etching.

Table 8-4 Summary of Applications and Management Options		
Application	**Management Option**	**Performance**
Graffiti Control on Masonry Substrates	Painting over	Unsightly
	Graffiti remover followed by high pressure water spray	Good option on some substrates
	Blasting system removal	Yes
	Graffiti resistant coating and graffiti remover	Good option on limited substrates
Graffiti Control on Street Signs	Non-sacrificial Films	Good option, may be warranty issues
	Graffiti resistant coating and graffiti remover	Warranty issues
	Sensitive surface graffiti remover	Depends on graffiti
Graffiti control on wood	Painting over	Good option
	Blasting systems	Less aggressive systems
Graffiti Control on Nonporous Surfaces	Graffiti remover	Good option
	Graffiti resistant coating and graffiti remover	Graffiti removal more difficult
	Painting over	Coating type may not match
Glass graffiti or etching	Sacrificial films	May protect against etching
	Graffiti resistant coating	May protect against etching
	Graffiti remover	Won't protect against etching

8.5.Health and Environmental Issues

Many of the graffiti removers used today contain toxic components like methylene chloride and NMP that can expose workers and community members to risks. MSDSs for commercial graffiti removers often do not identify a significant portion of the formulation. Agency personnel should ask suppliers for this information to determine whether other toxic components may be present in the graffiti removers. Graffiti resistant coatings may also contain toxic carrier solvents and agencies should evaluate MSDSs carefully to determine this. Coatings containing TBAC should not be used at all. Blasting technologies may release free silica which can cause lung disease from masonry surfaces; wet technologies are a better option for minimizing this problem.

Many commercial graffiti removers on the market today do not comply with the VOC regulations established by CARB. A number of the graffiti resistant coatings offered by suppliers similarly do not comply with air district regulations. Agency personnel should ensure that any products they use are compliance with the VOC regulations.

The stormwater zero discharge requirements in most of the state mandate that the spent media from blasting operations be collected and not released to stormwater. DTSC regulations on hazardous waste require analysis of spent material before it can be released to land. Blasting technologies that minimize the generation of secondary waste are one option for managing this problem. Some technologies like dry ice blasting require certification by CARB before they are used. Other technologies, like crushed recycled glass blasting, require a SCAQMD permit.

IX. References

(CARB, 2005) California Air Resources Board 2003 Consumer and Commercial Products Survey, Table B. Can be accessed at www.arb.ca.gov/consprod/regact/2003surv/tableb.pdf.

(CARB, 2012) California Air Resources Board, Final Regulation Order, Regulation for Reducing Emissions from Consumer products, Subchapter 8.5 Consumer Products. Can be accessed at www.arb.ca.gov/consprod/regs/2012/article2080913.pdf.