A Hedonic Analysis of Combined Sewer Overflows (CSOs) in Northern New Jersey

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Abstract

Significant water pollution caused by flooding due to heavy precipitation and extreme weather events such as Hurricane Sandy and similar storms of the past have become a considerable problem, and changing weather patterns and sea level rise attributable to global climate change stand to further exacerbate the issue. During heavy precipitation events, combined stormwater and untreated sewage may be diverted to adjacent water bodies, resulting in contamination and water pollution that can be harmful to human and environmental health. This contamination, especially in urbanized areas of northern New Jersey, is largely a product of discharge events from combined sewer overflows (CSOs). Though the effects of the contamination caused by polluted water discharge through CSOs has been studied by some researchers, the socio-economic aspect of these issues has not received much scientific attention. This study seeks to understand the socio-economic facets arising due to of the continued use of CSOs in Elizabeth, Newark, and Paterson by using a hedonic analysis of homes near CSOs to evaluate its detrimental effect on the price of residences in these urban areas. We use real estate and county data in a GIS overlay to map residences and features in these urban New Jersey areas and undertake geospatial analysis to reveal the effects of household, neighborhood, and environmental attributes on sale price. We use the data from GIS analysis in logistic regressions in order to analyze the significance of a number of these factors, including proximity to the nearest CSO, and estimate the economic effect that each factor has on a residence’s final price. This information is critical for revealing the socio-economic consequences of continued CSO operation, and can provide data for preventing the worst of CSO problems in the case study cities and similar urban areas. Further, these results can be used to inform CSO management strategies, including the use of green infrastructure, to understand economic impacts and intuit public perceptions of various strategies.

1. Introduction

Historically, New Jersey has continually struggled with different environmental issues stemming from its rapid and widespread urbanization. One of such problems that has become more prevalent over time with increased population density is the frequency of discharges from combined sewer overflow (CSO) systems. Discharges from these systems are a significant concern for human and environmental health during rainfall events due to the pollutants they release into local waterways. In the wake of Hurricane Sandy and similar storms in the past, New Jersey has become increasingly aware of the damage that large storms have the potential to cause, and have begun to seek out ways to reduce damage and become more resilient.

CSOs, particularly during heavy rainfall events, can release discharges containing significant levels of pollutants, notably human sewage, garden waste, chemicals, oils, and residential pollution into nearby waterways; the EPA estimates that over 23 billion gallons of untreated sewage may be discharged into North Jersey waters due to CSO failures annually (EPA 2012). Urban areas, which are characterized by a high percentage of impervious surface, are particularly vulnerable to these events because water cannot infiltrate easily, and rainfall events that are not particularly significant may still cause CSOs to be overwhelmed; some urban areas of New Jersey can be overwhelmed with as little as one inch of rainfall (Battelle 2005, Donovan et al. 2007). These discharges therefore lead to untreated waste entering waterways, creating a notable health risk for both the environment and humans in the form of microbial and environmental contamination; the EPA estimates that between 1.8 and 3.5 million people become ill due to recreational contact with water contaminated by sewer outfalls (Veronesi et al. 2014). Though disastrous storm events are the biggest concern for contamination, even mild amounts of rainfall can be the cause of significant contributions to local waterway contamination (Casadio et al. 2010). Changing water dynamics and other uncertainties caused by global climate change have given this issue more urgency, as increased discharge from CSOs brought on by rising water levels or increased storm frequency or strength could make this contamination more common (Jagai et al. 2015, Keupers and Williams 2013).

While installation and maintenance costs of different grey CSO solutions are fairly well documented, less attention has been paid to the socio-economic aspects of CSOs and other solutions such as green infrastructure. Those residing within close proximity to CSOs stand to feel the effects of CSO-created pollution most strongly, making community acceptance of CSO solutions of upmost importance. As such, this study attempts to examine these issues using a hedonic modeling approach. The hedonic analysis aims to delineate the effect that proximity to a CSO outfall has on a property value, which in turn can help to inspect the effect on CSOs on the housing market overall and how those most affected by CSOs due to their proximity are affected economically. This technique aims to provide a more complete picture of the costs and benefits of CSO infrastructure by taking into account the costs that individuals perceive or must deal with as a result, and the effect that it has on the economy of the area. This study seeks to fill a gap in the research by using this hedonic method to evaluate the disamenity value of CSO discharge outfalls. As CSOs remain prominent in the American Northeast and elsewhere in the United States, this study could provide telling data to assist management officials in this area with financial decisions in the face of a growing effort by the USEPA and NJ Department of Environmental Protection to mitigate CSO risks.

2. Methodology

2.1. The Hedonic Model

Hedonic analysis is an econometric method that compares homes with similar observable attributes and evaluates the influence of positive (waterfront view, beach access) and negative (near a landfill or polluted area) environmental factors on price (Ashford and Caldart 2008, Freeman 2014). This method uses a regression model to measure the marginal implicit price of each attribute, which represents the estimated price an individual would be willing to pay for it (Ashford and Caldart 2008). Recently, Geographic Information Systems (GIS) technology has been adopted for hedonic projects to provide more accurate analyses (Tietenberg and Lewis 2012); GIS allows for precise mapping for hedonic studies, allowing concise calculations for a number of different spatial variables that can provide data to inform regression analyses. By using this method, we may demonstrate a monetary loss in the housing market for homes near CSO outfalls in Newark, Elizabeth and Paterson due to health, environmental, and aesthetic concerns. By doing this, another cost associated with CSOs can be defined, perhaps offering further incentive to upgrade this infrastructure and remove the negative effects it has on housing in the area, strengthening the municipality's housing market and therefore its overall economy.

To estimate the hedonic pricing model, we utilized a regression analysis to demonstrate the relationship between housing price and household, neighborhood, and environmental variables. This study used a typical hedonic equation of housing price as elaborated as the following equation:

$$P_i = \beta_1 H_i + \beta_2 N_i + \beta_3 E_i + \varepsilon_i$$

where P_i is the price of property $_I$, H_i is a matrix of household characteristics of a property (such as flood zone and shape area), N_i is a matrix of neighborhood characteristics (such as distance to transit and distance to hospitals), E_i is a matrix of environmental characteristics (such as distance to parks and distance to CSOs). The ε_i's are the error terms and the β's estimate the coefficients associated with each of the independent variables included in the model.

It should be noted, however, that while hedonic pricing methods can be used to estimate the value associated with different amenities and disamenities, it generally cannot account for the full value of the characteristic (Ashford and Caldart 2008). Additionally, hedonic pricing usually best demonstrates the value of amenities that are highly localized, such as open space, as their effects are more likely to be capitalized on as opposed to more widespread effects, such as air quality, which will also have affect other homes in the area (Sander and Polasky 2009). As such, hedonic pricing can be trusted to create a partial, not total, estimate of the value of the environmental amenities (Ashford and Caldart 2008, Freeman 2014, Sander and Polasky 2009).

2.2. Study Area:

New Jersey is home to a significant number of CSO sites, particularly in the industrialized and urbanized areas in the northern part of the state. The Newark Bay and the Lower Passaic region of New Jersey are noted for the considerable pollution and contamination of water bodies, largely as a result of historical and continuing industrialization, manufacturing, and urbanization. Several water bodies, including the Passaic River, flow through this area, which is densely populated and industrialized. Nearly 40 CSO outlets discharge into the Newark Bay/Kill van Kull area, and another 22 discharge into other waterways in this region. This area has several of the factors that put it at risk for high frequency and volume of CSO discharge events, notably a large percentage of impervious surface. As such, this area experiences increased overland flow volume and frequency during rain events, resulting in flooding, and therefore CSO discharges. In the wake of Hurricane Sandy, in which large amounts of discharge contamination was released into local waterways, the state administration is taking steps to improve the resilience of this area and others in New Jersey that are at risk during future extreme weather events (USEPA 2016).

Newark, Elizabeth, and Paterson are all cities within this area that have some of the highest numbers of outfalls in the state, with 17, 28, and 24 outfalls, respectively (NJ Future). All three cities are among the highest population centers in New Jersey for both population and population density, which exacerbates the health issues that CSOs present. These cities also continue to grow, and considering that CSO discharges are strongly affected by stormwater runoff due to impervious urban surfaces, these cities serve well as examples for areas vulnerable to worsening consequences of using CSOs. It is also worth noting that these cities all suffered damages during Hurricane Sandy in 2011, and were subject to considerable contamination stemming from CSO discharge events throughout the storm. Further, these areas have high rates of poverty, low college graduation rates, and high minority populations, which can make these areas of note for environmental justice concerns. The 2010 census data for these areas is summarized in Table 1 below:

Table 1: Census and EPA Population and Demographic Statistics for Study Areas

	Newark	Elizabeth	Paterson
Population	281,944	129,007	147,754
Number of CSOs	17	28	24
Percent below poverty line	29.9%	19.2%	28.4%
Demographics	White 26.3% Black 52.4% Hispanic/Latino 33.8%	White 54.6% Black 21.1% Hispanic/Latino 59.5%	White 34.7% Black 31.7% Hispanic/Latino 57.6%
College Education	13.3%	6.3%	10.7%
Median Home Value	$229,600	$271,400	$262,200

2.3. Data

Data used in this study came from a variety of sources. Home prices and their structural characteristics were obtained from real estate databases in order to use the most up to date and accurate information. For the purposes of this study, real estate data provided a consistent and singular set of data, and did not have many of the pitfalls of data obtained from tax records (data gaps, differing characteristic data, and large outliers in the data). We used properties sold in the study areas over 5 years (2013-2017) to provide a reasonable sample size and subsequently capture observations under a relatively stable market, as reaching further back in time may have clouded the data due to the recent market crash and housing crisis. In doing so, we sacrificed a larger dataset with tax records for more accurate, up to data information on a smaller sample size. In order to ensure that the prices were comparable in terms of inflation, we standardized the data using Federal Reserve Economic Data from the Federal Reserve Bank of St. Louis. For as much accuracy as possible, we adjusted for inflation over the timespan using unique datasets for each of the counties in which the study sites were located.

These characteristics were merged with existing data layers for the target cities, which were downloaded from the New Jersey Transportation Planning Authority (NJPTA). Additional data layers, including locations for rivers, parks, CSOs, and flood zones, were taken from other online GIS databases, including the NJDEP Bureau of GIS database and FEMA databases. This data contained parcels in GIS for every residential property in the studied cities, but excludes rental properties, as their price may not accurately convey the monetary value of the property. Distances for the variables that require them were measured via GIS using the "Generate Near Table" tool, which measures raw distance ("as the bird flies") as opposed to driving distance. We decided on using raw distance rather than driving distance due to the nature of CSO contamination, particularly in terms for its ability to be aerosolized and create local hazards regardless of driving distances.

With considerations for the availability of data and after analyzing common trends in existing studies in the literature (Asami 2001, Czembrowski and Kronenberg 2016, Eshet 2007, Lowicki and Piotrowska 2015, Panduro and Veie 2013, Sander and Haight 2012, Sander and Polasky 2009, Schläpfer et al. 2015, Yamagata et al. 2016), the factors in Table 1 were chosen to be calculated for the final analysis. We decided on a number of structural, neighborhood, and environmental factors that were likely to have some effect on the pricing of a home.

Table 1: Factors for Hedonic Analysis

Variable Name	**Variable Class**	**Definition**	**Hypothesized Relationship to Sale Price**
Shape_Area	Household	Calculation of the area of the residential parcel in meters.	Positive
Fld_zone	Household	Dummy variable indicating whether residence is (1) or is not (0) in a FEMA flood zone.	Negative
Rooms	Household	Rooms in the house	Positive
Bedrooms	Household	Bedrooms in the house	Positive
Bathrooms	Household	Bathrooms in the house	Positive
Garage	Household	Indicates the size of the garage in terms of car occupancy (0 for no garage)	Positive

Basement	Household	Dummy variable indicating basement (1) or none (0)	Positive
Distance_to_CSO	Environmental	Distance to closest combined sewer overflow in ft	Positive
Distance_to_Park	Environmental	Distance to closest park in meters	Negative
Distance_to_Transit	Neighborhood	Distance to closest train station in meters	Negative
Distance_to_Water	Environmental	Distance to nearest waterway in meters	Negative
Distance_to_Hospital	Neighborhood	Distance to the nearest hospital in meters	Negative
Distance_to_Police	Neighborhood	Distance to nearest police station in meters	Negative

Household factors in the hedonic analysis are inherent in the property itself, and include items such as shape area and various rooms .We hypothesize that more rooms of any kind (including the basement) will increase home values, as will garages, especially in urban areas such as these where street parking is often difficult to come by. Rooms, bedrooms, and bathrooms are all important constants in hedonic analyses, and using real estate data gave us a complete picture of these data points for the properties in question. Whether or not the residence lies within a FEMA flood zone was the final household variable tested, as homes along the water may be less attractive within these zones due to the possibility of damage from future storms. While other studies in the literature address age of the residence, we did not use this variable; due to a lack of consistent or verifiable data in both the real estate dataset and the municipal dataset, adding this variable to the analysis would have eliminated a considerable number of observations.

Variables capturing the neighborhood characteristics included distance to transit centers, distance to police stations, and distance to hospitals. The map points for all of these factors were plotted using municipal data from the county or the state, as many of the factors represent public buildings that the county is responsible for. Crime can be a concern in many areas of Northern New Jersey, and the cities used in this analysis are no different. In order to represent this, we originally looked to a number of different sources, including federal, private, and public databases and researched groups in order to map areas by crime, but found that the data could be inconsistent in its reporting and its boundaries for areas high or low in crime, and that there was no clearly accurate source for a GIS map layer. Thus, we used distance to the closest police station as a representation of safe and unsafe areas. Transit centers are of high importance in these areas due to the commonplace practice of commuting into nearby New York for employment. Finally, hospitals can be a useful consideration for house prices, as while providing a service, can also be a source of nuisance for residents due to the sirens of the ambulances coming in and out. Notably, we do not address school districts in this analysis; because urban areas often have several school districts, simply mapping the nearest schools would have been insufficient to accurately note the effect of school district on pricing. Further, though lack of data is unfortunate, there is considerable precedent for excluding this factor in the literature (Yamagata et. al 2016, Schlapfer et. al 2015, Panduro and Veie, 2013, Votsis 2017).

The environmental factors were the final subset of data in our analysis, and included factors that are not necessarily a part of residences themselves, but focus on the distance to different environmental amenities or disamenities and how they affect home prices. Parks have several benefits to residents, including adding greenery to an otherwise urban area and providing a place for social and recreational activity. Residents may also value parks not only for recreation and aesthetics for their ability to mitigate flooding issues via infiltration. Proximity to waterbody is often also a very sought after amenity in a residence. In Newark and Elizabeth specifically, some waterways provide a view of New York City, which may also enhance its value. Distance to the nearest CSO discharge point is of course the key factor in the study, and measures the raw distance between a CSO and a residence. CSOs are, as explained in the literature review, dangerous from human and environmental health perspectives, and thus it was expected that close proximity to CSOs could negatively impact the sale price of a residence.

2.5. Data Compilation and Analysis

After compiling the data, we used ARCGIS Mapping software to map the residential parcels. We had a total sample of 2957 parcels altogether, with 1005 in Elizabeth, 1020 in Newark, and 930 in Paterson. We then used municipal shape files to add layers for the majority of the neighborhood variables, including police stations, hospitals, waterways, CSOs, parks, and transit stations. Using FEMA data, we also added a layer to include their flood zones, and designated residences within or outside of the layer. Using the “Generate Near Table” tool in ArcGIS, the three residential data sets were compared to the closest object on the map in its respective category, generating a number of map layers and tables.

Upon completion of the mapping steps, the tables were joined and exported into an Excel table, where they were again compiled into a single table for analysis. We used JMP analytical software to examine and clean the data. To do this, we excluded blank observations, including ones that appeared to be in error. Specifically, observations whose number of rooms or bathrooms were zero were excluded from the analysis. We also excluded observations below with sale prices below $10,000 or above $1 million, as they appeared to be outliers. In order to ensure validity of the data, we also eliminated any residences that appeared multiple times with identical information. After checking the data for normality, we chose to take the log of both the adjusted sale price and last year tax in order to improve accuracy. Finally, we ran tests for normality, error, and outliers, and used a Cook's D test to remove observations that were having a significantly disproportionate influence on the model. Using these guidelines for cleaning the data, we eliminated 621 observations from the total dataset, leaving a final dataset of 2336 observations for analysis. Finally, we used JMP to analyze the data in an ordinary least squares (OLS) regression. We compared the models for Adjusted Sale Price and the log of Adjusted Sale Price, and due to a significantly higher R^2 value for the latter, used that for the final analysis.

3. Results and Discussion

After running the regression analysis using Adjusted Sale Price as the independent variable, we arrived at the final hedonic model, as demonstrated in section 3.1. The results of this analysis are shown below, in Table 2. The model had a R^2 value of .30 and a P value of <.0001, with a total of 2336 observations.

Table 2: Results of Hedonic Regression with Adjusted Sale Price as Independent Variable

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	59914.81	16718.96	3.58	0.0003*
Rooms	14252.85	1784.07	7.99	<.0001*
Bedrooms	873.37	2470.47	0.35	0.7237
Bathrooms	33517.53	4002.46	8.37	<.0001*
Garage	21146.67	2929.14	7.22	<.0001*
Basement [No]	3066.28	5009.50	0.61	0.5405
Flood zone [0]	-37059.97	10431.61	-3.55	0.0004*
Distance to water (M)	-24.15	5.77	-4.18	<.0001*
Distance to police station (M)	10.26	5.70	1.80	0.0720
Distance to park (M)	-1.12	0.29	-3.85	0.0001*
Distance to public transit (M)	-8.99	4.14	-2.18	0.0297*
Distance to hospital (M)	8.17	3.62	2.26	0.0242*
Shape_Area	14.61	1.38	10.61	<.0001*
Distance to CSO (M)	-5.94	2.12	-2.80	0.0052*

After analyzing the hedonic regression, several variables proved to be significant, though not necessarily in the ways that were hypothesized. Basement, bedrooms, and distance to police all proved to be insignificant in the final regression. The presence of a basement was hypothesized to have a positive effect on price since these areas are highly urban where space is limited, though in these areas in the dataset, it appears to be less important. Similarly, the number of bedrooms was insignificant. Distance to police stations was also not significant, which may suggest either that proximity to police stations is not prioritized in cities where the distance may have only a minor effect on response time, or that distance to these stations is not an appropriate measure of safety for a homeowner.

Household variables, exempting the aforementioned ones, performed relatively as expected. Both number of rooms and number of bathrooms proved significant and represented a considerable boon for home prices. The presence of a garage, too, added value to the home, likely as a result of the difficulty of urban street parking and thus the value of a guaranteed place to park. Shape area performed as predicted, as larger houses with larger tracts of land tend to be more valued, especially in urban areas where space is at a premium. The testing for flood zone, however, did not perform as expected, as homes that were not in the flood zone were significantly less valued than those within the flood zone. This can likely be explained by flood zone areas, as a rule, being closer to the waterfront, which is generally a desirable area to live. We expand on this further later in this section.

Of the neighborhood values, distance to transit and distance to hospital were both significant, though to the 95th percentile as opposed to the 99th that many of the other factors were. As expected, distance to transit stations had a significant negative coefficient, which marks it as having an amenity value. Prices rise as proximity increases to the transit stations; this matches expectations, as these areas, like many in Northern New Jersey, house many commuters to New York or New Jersey cities, making transit valuable. While we hypothesized that a proximity to hospitals would represent an amenity, the opposite has proven to be true in the analysis. While a proximity to an emergency facility could be useful in certain situations, it's likely that the far more common situation of noise pollution from sirens instead turns this proximity into a nuisance, which could explain the results of the regression.

The environmental variables, distance to water and distance to parks, were both significant and behaved as hypothesized. Parks, representing green spaces of relative rarity in urban areas, carried a small but significant amenity value. Waterways, however, represented perhaps one of the largest amenity values in the study at a change of nearly $25 per meter away from the waterway. As hypothesized, the desirability of living near waterway for the views it affords proved to increase the price of a home, despite complications such as a stigma of polluted waterways, especially in the Newark and Elizabeth areas.

Distance from CSOs was the final significant variable among those that were chosen for the analysis, and had a negative value of -$5.94. As such, the analysis suggests that CSOs are a desirable factor. While this seems paradoxical in light of the dangers of CSOs, there may several factors at play that influence this result. First and foremost, while distance to waterways and distance to CSOs are discrete factors that did not have significant correlations in testing, the simple fact remains that CSO discharge sites, as a rule, are located at waterways. Since proximity to water was found to be significantly desirable in this analysis, we hypothesize that this amenity value may override the negative effects presented by CSOs. In addition to this, it may be that the public is unaware of the dangers of CSOs; excepting days when significant signs of CSO discharge are obvious (such as strong odors), it may be that residents near discharge sites are unaware that these sites contain pollutants or are harmful to their health in any way.

Further, while this study utilizes several residential, neighborhood, and environmental factors with studies in environmental hedonic analyses, there are few studies in which a majority of these factors were found. However, comparisons can be made to results found in the literature that support our own results.

Though the study areas varied widely in the cited literature, including the United States and abroad, many studies used distance to water as a factor. Whereas in this study, any nearby water source was used for the distance, a variety of terms and subdivisions were used for factors concerning water, including “lakes,” “oceans,” “streams,” and “ponds.” When these factors are considered all as a similar “water” factor, our study concurs with others in the literature that the value of these water factors are negative, and therefore have an amenity value that adds to the price of a residence (Sander and Polasky 2009, Sander and Haight 2012, Yamagata et. al 2016, Schlapfer et al. 2015). Similar conclusions can also be drawn from distance to parks, which also proved to have a negative coefficient and therefore amenity value, confirming findings of other studies in the literature (Sander and Polasky 2009, Sander and Haight 2012, Yamagata et al. 2016, Schlapfer et al. 2015, Czembrowski and Kronenberg 2016). Our only other environmental variable, distance to CSOs, as mentioned earlier, is largely absent from hedonic studies. Our regression results were, however, opposed by the literature for some of the neighborhood variables, namely distance to transit hubs, which had a positive value to represent a disamenity value in the literature (Sander and Polasky 2009, Yamagata et al. 2016, Czembrowshi and Kronenberg 2016). Some of the factors used were not common in the literature and did not have a base of comparison to test them against, and therefore it is somewhat difficult to judge whether or not our results were consistent with a larger literature base.

The hedonic method, despite its versatility, entails certain challenges and the results should be interpreted accordingly. Since housing price is a critical part of the analyses, for instance, the scope of environmental benefits that can be measured using hedonic analyses are limited to attributes that are related to housing prices. Differences in environmental attributes are also considered to directly affect property value; if individuals do not recognize the link between an environmental attribute and its effect on their property, it is unlikely that differences in the environmental attribute will be reflected in their property value. By directly linking differences in environmental attributes to property value, the method also inherently assumes individuals recognize the direct relationship between the environmental attribute of interest and property value. While this assumption may hold for some individuals and for some types of environmental attributes, it applications for lesser known environmental attributes and across all individuals could be improbable. The role of exogenous factors, including interest rates, is also not always included in the analyses. Lastly, the approach assumes that individuals have opportunities to select combinations of features they prefer given their income. If their options are limited, determining the value of environmental attributes accurately could be challenging.

4. Conclusions and Future Study

The hedonic analysis using the data that we have collected suggests that the effects of combined sewer infrastructure do not have economic consequences in the housing market. In the three cities we studied, proximity to CSO discharges were found to have an amenity effect on the prices of homes near them, and it can therefore be surmised that residents in this area do not value living farther away from CSO discharge points, and therefore will not pay a premium to avoid them. However, due to the nature of the study, it is unclear whether or not this points to a populace that is uneducated on the possible dangers of CSO discharges or if residential prices are simply reflecting more common trends tied to the desirability of residences near waterways. While the hedonic regression failed to find a disamenity effect tied to CSOs, this in itself can provide insight into possible action by policy makers and city planners. The apparent amenity value of CSOs is paradoxical given the harmful nature of these areas, and it can therefore be inferred that residents are not thoroughly aware of the dangers that these discharges can represent. Efforts should be made to educate the populace on these potentially harmful areas, both to inoculate residents against the dangers of these areas and to perhaps reveal more coherent links between CSOs and the economy.

While this study can potentially add some important socio-economic data to cost benefit analyses for the study areas and areas similar to them, the results are by no means comprehensive or indicative of all cities of their type. Future research could expand on this theme by including more factors in the hedonic analysis and analyzing different areas to provide a more robust base of research for cities looking to phase out their CSO infrastructures. Ideally, this study and future ones may be used to craft education and outreach tools to inform and protect the public.

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